
A Background Study of Trout (Embury) and Cliff Lakes

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**Manitoba
Environment and
Workplace Safety
and Health**



A BACKGROUND STUDY

OF TROUT (EMBURY) AND CLIFF LAKES

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ABSTRACT

Prior to development of the Trout Lake Mine, background water quality data was gathered in July, 1981 for Trout (Embury) Lake and Cliff Lake. Water column physicochemistry and benthos populations were consistent with an ultra-oligotrophic classification for Trout Lake and an oligotrophic classification for Cliff Lake. Elevated copper and zinc levels in the water column, sediments and fish muscle tissue of both Trout Lake and Cliff Lake were attributed to aerial deposition from the Hudson Bay Mining and Smelting Co. base metal smelter in Flin Flon. Elevated arsenic concentrations in sediments and fish muscle tissue were probably derived primarily from geological sources. It could not be firmly established that lead, mercury and cadmium were derived from anthropogenic sources.

SUMMARY

A joint venture development of Trout Lake Mine was proposed for the western shore of Trout Lake. The proposal raised concerns regarding potential degradation of source waters for Flin Flon's water supply. A predevelopment study was planned for Trout Lake and Cliff Lake in order to provide a background against which environmental control measures proposed for the minesite could be assessed. Water column physicochemistry, metal concentrations in sediments and fish muscle tissue, benthic populations and phytoplankton populations were examined.

It was determined that Trout Lake was best classified as ultra-oligotrophic while Cliff Lake was best classified as oligotrophic. Moderate benthic productivity rates and high diversity indices were consistent with these classifications.

Metal concentrations in the water column, sediments and fish muscle tissue provided opportunity for comparisons to several earlier investigations. Consistent with assessments of the earlier studies, it was concluded that copper and zinc were loaded at differing rates to Trout Lake and Cliff Lake due to aerial deposition from the Flin Flon smelter stack emissions. Contrary to some studies, it was concluded that arsenic concentrations in the two lakes were primarily derived from natural geological sources. Also unlike some studies, it was concluded that a definite link between lead, mercury and cadmium concentrations to anthropogenic sources could not be firmly established. Evidence of nickel loading was not found.

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INTRODUCTION

Hudson Bay Mining and Smelting Co. Ltd. has assumed the lead role in a joint venture* development of Trout Lake Mine (21-67-29W) on the western shore of Trout (Embury) Lake ($54^{\circ}49'$, $101^{\circ}48'$; Figure 1). Development and initial operational mine wastewaters were directed to Gill Lake ($54^{\circ}48.5'$, $101^{\circ}40'$). Upon completion of a conduit line (October 29, 1982), mine wastewaters were thereafter discharged to Flin Flon Creek.

The source of Flin Flon's water supply (Cliff Lake; $45^{\circ}49'$, $101^{\circ}51'$) is recharged by pipeline from Trout Lake. Thus, concerns have arisen regarding potential degradation of source waters by drainage from the mine site and by possible ruptures of the mine wastewater conduit line. Additionally, the ultra oligotrophic nature of Trout Lake renders it highly sensitive to environmental impacts.

This predevelopment study sought to address these concerns by establishing a background data base for each of Trout and Cliff Lakes. This information will be used as a baseline to assess future impacts of the operation. Specific environmental components investigated included water physicochemistry, metal levels in sediments and in the muscle tissue of resident fish species, as well as population characteristics of phytoplankton and benthic organisms. Assessments of Trout Lake's fish population structure were conducted by regional staff of the Department of Natural Resources.

* Hudson Bay Mining and Smelting Co. Ltd.'s partners in the joint venture are Manitoba Mineral Resources, Granges Exploration A. B. and Outokumpu Oy (Finland).

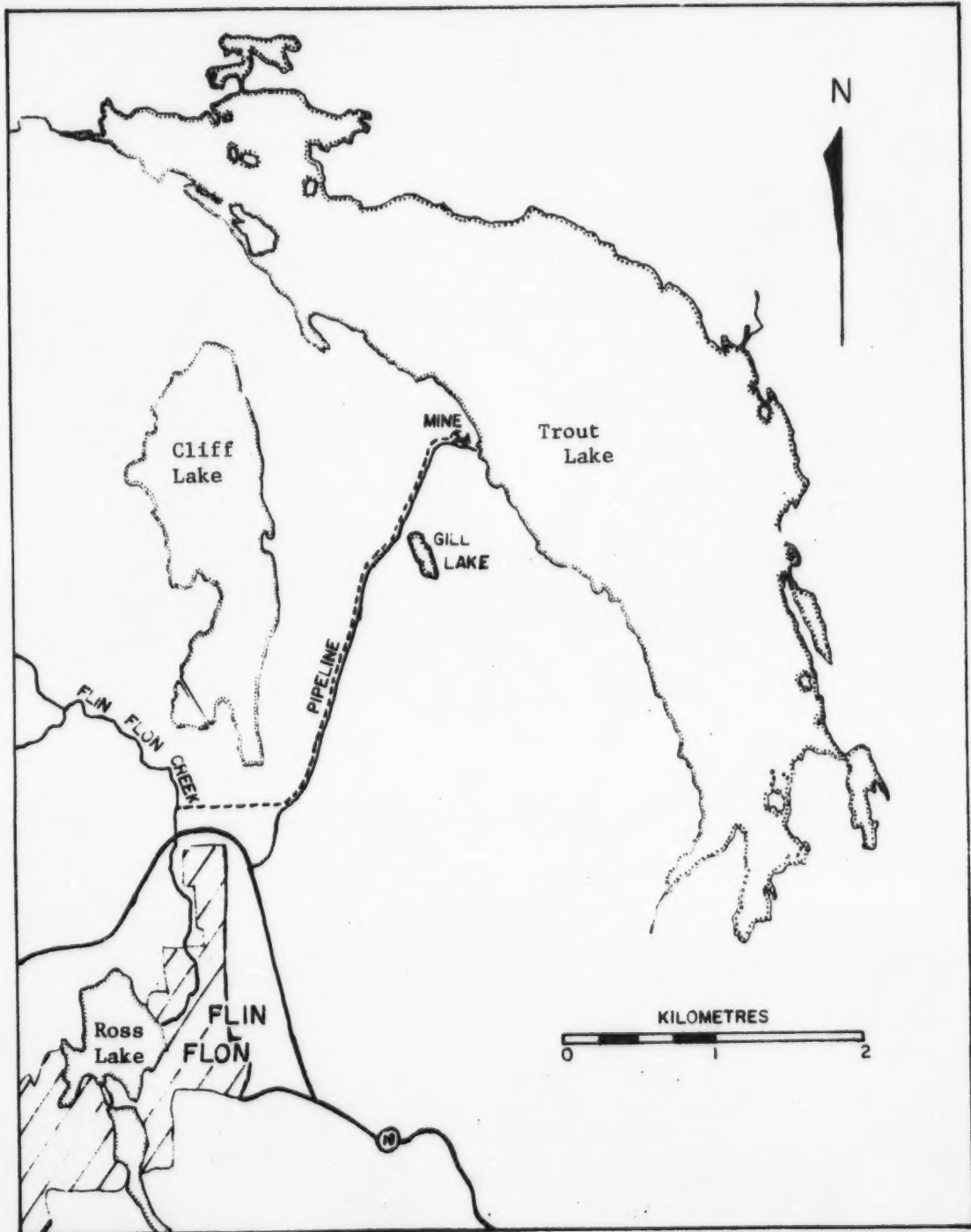


Figure 1: Overview of Study Area.

AREA DESCRIPTION

Trout and Cliff Lakes are situated in the Precambrian Shield region immediately northeast of Flin Flon, Manitoba. Lake bathymetry and morphometry, along with surrounding vegetation were described in Wilson, 1982. Local geology has been described by Davies et al (1962).

STUDY METHODS AND MATERIALS

Field Methods

Random sampling stations (Figures 2 and 3) were located on each of the lakes by superimposing a numbered grid upon figures of each lake and utilizing random number tables to determine grid reference points. A total of thirty and fifteen stations were identified for Trout and Cliff Lakes, respectively. These locations were then sampled for water, sediments, benthos and phytoplankton. Sampling of the two lakes was conducted from July 11 to 16, 1981.

Water

Depths for collection of water samples were determined prior to sampling by considering random numbers as a percentage of the total depth at each station (Appendix 1a; Appendix 1b). Water samples were collected with a trace metal grade four-litre acrylic Kemmerer sampler.

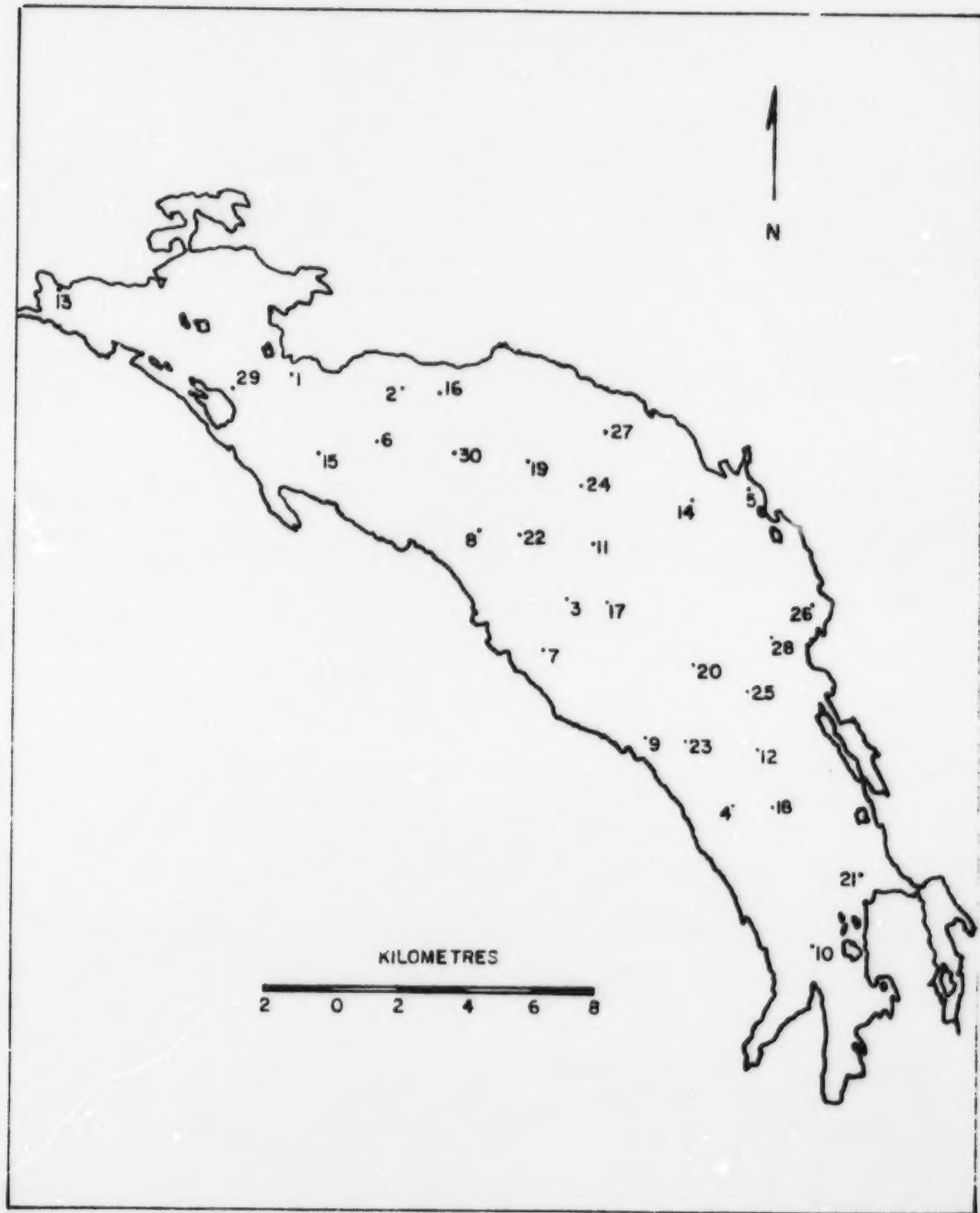


Figure 2: Trout Lake Sampling Stations.

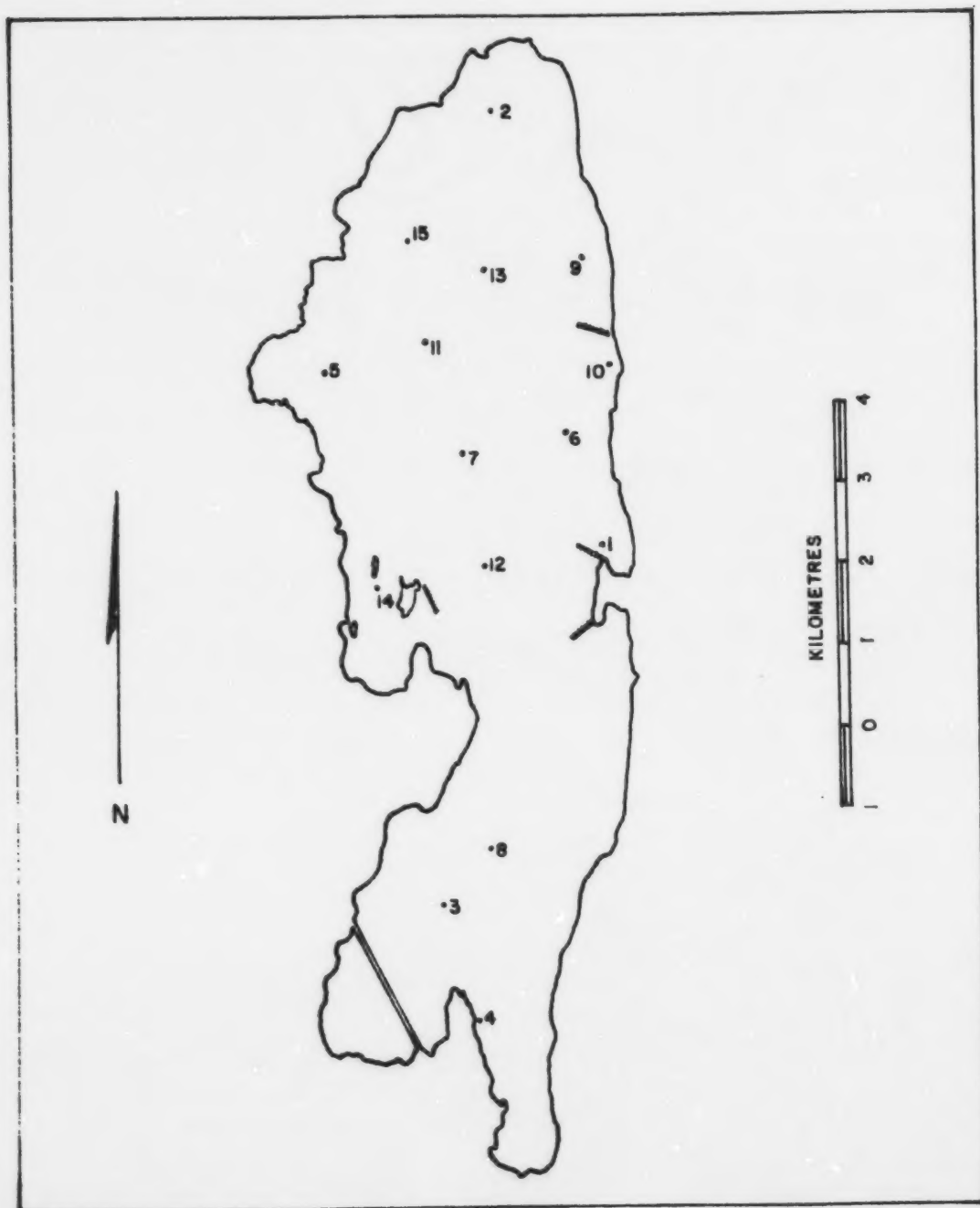


Figure 3: Cliff Lake Sampling Stations and netting Sites.

Essential preservatives (Sorba et al, 1980) were added immediately after sample collection. Samples were placed in coolers and shipped via scheduled bus service so as to arrive at the W. M. Ward Technical Services Laboratory within 24 hours of collection. Temperature and dissolved oxygen profiles were determined at stations 11 and 28 on Trout Lake by collecting samples at 2.0 m intervals from surface to bottom.

Sediments

Sediments were collected with a 22.9 cm square Ekman dredge. A five centimetre diameter acrylic tube was carefully inserted through the dredge contents so as not to disturb the sediment-water interface. Excess water and sediments more than five centimetres below the interface were carefully drained from the tube. The remaining sample was placed in a labelled "whirl-pak" plastic bag and stored frozen. Upon completion of field work, these were submitted to the W. M. Ward Technical Services Laboratory.

Duplicate sediment samples were collected from Trout Lake stations 5, 10, 15, 20, 25 and 30 and kept refrigerated. This procedure was repeated at Cliff Lake stations 5, 10 and 15. These were later submitted for total cyanide analysis.

Fish

Specimens and respective meristic data of Trout Lake fish were provided by regional Fisheries Branch staff of the Department of Natural Resources. Species provided included lake trout, northern pike, lake whitefish and common sucker. These had been collected by gillnet. Walleye were collected by angling in a bay near station 21.

Cliff Lake specimens were collected by various sized gill nets (76.2 mm, 95.3 mm, 108 mm and 127 mm mesh; stretch measure) deployed at various locations on the lake (Figure 3). Species involved included northern pike, walleye, lake whitefish and common sucker. Meristic data was obtained by measuring each fish to the nearest 0.1 cm (fork length), weighing to the nearest 10 g, sexing and removing evidences of age. (The latter was species dependant). Evidences of age were submitted for analysis to the Biological Services Branch of the Department of Natural Resources.

All species were sampled by obtaining skinless, boneless fillets. The fillets were placed in individually labelled "whirl-paks" and stored frozen until submission to the W. M. Ward Technical Services Laboratory.

Benthos

Benthic samples, like sediments, were collected with a 22.9 cm square Ekman dredge. Benthic grab samples were field sieved with a 0.4 mm mesh nylon bag in order to reduce bulk. Sieve contents were placed in labelled "whirl-paks" and appropriate volumes of the preservative Rose-Bengal solution (Mason and Yevich, 1967) were added. Samples were submitted for identification and enumeration to the W. M. Ward Technical Services Laboratory.

Phytoplankton

Phytoplankton samples were collected with a 2 litre acrylic Kemmerer sampler at random depths through the euphotic zone of each station. The euphotic zone was considered as extending from the surface to twice the secchi disc transparency. Random numbers were considered a percentage of the euphotic zone depth (Appendix 2(a-b)). Samples were concentrated by passing the Kemmerer contents through a 64 μ mesh Wisconsin plankton bucket. Samples were preserved with Lugol's Iodine Solution, sealed and shipped to the W. M. Ward Technical Services Laboratory for identification and calculation of estimated surface area (μ^2) per species. Samples were collected July 11, 1981 on Cliff Lake and July 15 to 16, 1981 on Trout Lake.

Analytical Procedures

Upon arrival at the W. H. Ward Technical Services Laboratory, samples were kept refrigerated or frozen (analysis dependent) until commencement of analysis. All analyses were conducted prior to sample shelf life expiration. Specific analytical methods are described by Sorba et al. (1980).

Resulting data were tabulated and summaries prepared. Water physicochemistry*, sediment metal concentrations and fish muscle tissue metal levels were compared at $t = 0.05$. Phytoplankton was examined quantitatively and qualitatively. Benthic populations were also examined quantitatively (densities per square metre) and qualitatively (H' diversity; Zand, 1976).

* After tabulation of Trout Lake data had been completed, it was observed that several parameters (conductivity, pH, zinc, and the alkalinities) at Trout Lake Station 19 appeared abnormal. Since this station had been sampled at 92% of the total depth and more than one retrieval of the sampler was required to fill all bottles, it was possible that bottom sediments were disturbed. This could have produced anomalies in the data.

Accordingly, Dickson's outlier test (P_{95}) was applied to the suspect parameters. Consequently, station 19 values for conductivity, pH, zinc and the alkalinities were rejected as outliers. The data summary (Table 1) was then prepared excluding these values.

RESULTS AND DISCUSSION

Water Physicochemistry

Trout Lake physicochemical data is detailed in Appendix 3 and summarized in Table 1. Cliff Lake data is detailed in Appendix 4 and summarized in Table 2. Interlake comparisons ($t = 0.05$) are presented in Table 3.

General Physicochemistry

A well defined thermocline was observed between the 14 m and 16 m levels on Trout Lake (Figure 4). Hypolimnetic temperatures ranged from 7.0°C to 9.0°C while epilimnetic temperatures ranged from 19.0°C to 16.0°C. The stratification was expected to remain stable throughout the summer months due to the 43.3 m maximum depth of Trout Lake. A thermal profile was not conducted on Cliff Lake because evidence of stratification was not encountered at the deepest station sampled (Station 7, 17.4 m). Temperatures ranged from 19.0°C at the surface to 11.0°C at 17.4 m.

Saturation levels of epilimnetic dissolved oxygen ranged from 118% to 99% at the profiled stations (Figure 4) of Trout Lake. Supersaturation of the epilimnion was attributed to wind action. Saturation levels of hypolimnetic dissolved oxygen ranged from 79% at bottom to 104% (Figure 4). Saturation levels in Cliff Lake ranged from 96% to 73%. Mean dissolved oxygen concentrations in Trout Lake (9.8 mg/L) were significantly greater than Cliff Lake (8.7 mg/L).

TABLE 1: Summary of Trout Lake Water Physicochemistry*

PARAMETERS	X	δ	Hi	Lo	n
Field Temperature °C	15.8	3.13	19.0	10.0	30
Conductivity $\mu S/cm$	120	0.59	121	119	29*
Residue Non Filt. mg/L	<5.0	0.0	<5.0	<5.0	28
pH units (log.)	7.70	---	7.95	7.5	29*
Alkalinity (Tot. $CaCO_3$) mg/L	41.0	0.50	42.0	40.2	29*
Alkalinity (HCO_3) mg/L	50.0	0.58	51.2	49.0	29*
Alkalinity (CO_3) mg/L	0.0	0.0	0.0	0.0	29*
Alkalinity (OH) mg/L	0.0	0.0	0.0	0.0	30
Dissolved Oxygen mg/L	9.8	0.53	10.7	9.0	30
T.O.C. mg/L	11.6	0.99	13.5	10.0	30
T.I.C. mg/L	8.6	1.14	10.5	6.5	30
Turbidity NTU	1.3	1.39	8.5	1.0	30
Nitrogen (Tot. Kjeldhal) mg/L	0.5	0.05	0.5	0.4	30
NO_3-NO_2-N (Diss.) mg/L	0.01	0.007	0.03	<0.01	30
P-Total mg/L	0.010	0.002	0.02	0.007	30
Cyanide (Tot.) mg/L	<0.02	0.0	<0.02	<0.02	30
Cyanide (Free) mg/L	<0.02	0.0	<0.02	<0.02	30
As (Tot.) mg/L	0.002	0.0005	0.003	0.002	30
Cd (Ext.) mg/L	<0.005	0.0	<0.005	<0.005	30
Cu (Ext.) mg/L	0.024	0.017	0.075	0.010	30
Pb (Ext.) mg/L	<0.005	0.0	<0.005	<0.005	30
Mn (Ext.) mg/L	0.007	0.0064	0.029	<0.005	29*
Zn (Ext.) mg/L	0.30	0.010	0.31	0.28	30
Ca (Ext.) mg/L	16.	4.0	23.	13.	30
Mg (Ext.) mg/L	4.3	0.447	5.0	3.5	30
Mg (Tot.) $\mu g/L$	0.03	0.015	0.07	<0.02	30

Note: x = mean

 δ = standard deviation

Hi = greatest value observed

Lo = smallest value observed

n = number of observations

*Station 19 values deleted from calculations per footnote, page 9

TABLE 2: Summary of Cliff Lake Water Physicochemistry

PARAMETERS	X	s	Hi	Lo	n
Field Temperature °C	17.4	2.87	19.0	11.0	15
Conductivity µS/cm	124	0.63	125	123	15
Residue Non Filt. mg/L	<5.0	0.0	<5.0	<5.0	15
pH units (log.)	7.79	---	8.00	7.15	15
Alkalinity (Tot. CaCO ₃) mg/L	40.5	0.27	41.0	40.0	15
Alkalinity (HCO ₃) mg/L	49.4	0.29	50.0	48.8	15
Alkalinity (CO ₃) mg/L	0.0	0.0	0.0	0.0	15
Alkalinity (OH) mg/L	0.0	0.0	0.0	0.0	15
Dissolved Oxygen mg/L	8.7	0.33	9.4	8.0	15
T.O.C. mg/L	11.5	0.72	12.5	10.0	15
T.I.C. mg/L	8.5	0.77	10.0	7.0	15
Turbidity NTU	1.20	0.25	1.5	0.9	15
Nitrogen (Tot. Kjeldhal) mg/L	0.4	0.0	0.4	0.4	15
NO ₃ -NO ₂ -N (Diss.) mg/L	0.01	0.0	0.01	<0.01	15
P-Total mg/L	0.014	0.004	0.021	0.009	15
Cyanide (Tot.) mg/L	<0.02	0.0	<0.02	<0.02	15
Cyanide (Free) mg/L	<0.02	0.0	<0.02	<0.02	15
As (Tot.) mg/L	0.004	0.002	0.010	0.002	15
Cd (Ext.) mg/L	<0.005	0.00	<0.005	<0.005	15
Cu (Ext.) mg/L	0.032	0.016	0.07	0.012	15
Pb (Ext.) mg/L	<0.005	0.0	<0.005	<0.005	15
Bi (Ext.) mg/L	0.006	0.004	0.015	<0.005	15
Zn (Ext.) mg/L	0.39	0.068	0.57	0.34	15
Ca (Ext.) mg/L	15.	1.00	18.	13.	15
Mg (Ext.) mg/L	4.6	0.32	5.0	4.3	15
Mg (Tot.) mg/L	<0.02	0.0	<0.02	<0.02	10

Note: x = mean

s = standard deviation

Hi = greatest value observed

Lo = smallest value observed

n = number of observations

TABLE 3: Comparison ($t \alpha = 0.05$) of Trout Lake and Cliff Lake Water Physicochemistry.

PARAMETERS	t	Critical Value at $t \alpha = 0.05$	Lake* with Higher Value
Field Temperature °C	1.71	2.0169	N.S.
Conductivity $\mu\text{S/cm}$	20.40	2.0183	Cliff
Residue Won Filt. mg/L	0.0	2.0197	N.S.
pH units	1.54	2.0183	N.S.
Alkalinity (Tot. CaCO_3) mg/L	4.31	2.0183	Trout
Alkalinity (HCO_3) mg/L	6.10	2.0183	Trout
Alkalinity (CO_3) mg/L	0.0	2.0183	N.S.
Alkalinity (OH) mg/L	0.0	2.0169	N.S.
Dissolved Oxygen mg/L	8.53	2.0169	Trout
T.O.C. mg/L	0.39	2.0169	N.S.
T.I.C. mg/L	0.35	2.0169	N.S.
Turbidity NTU	0.38	2.0169	N.S.
Nitrogen (Tot. Kjeldhal) mg/L	10.95	2.0169	Trout
$\text{NO}_3\text{-NO}_2\text{-N}$ (Diss.) mg/L	0.0	2.0169	N.S.
P-Total mg/L	3.65	2.0169	Cliff
Cyanide (Tot.) mg/L	0.0	2.0169	N.S.
Cyanide (Free) mg/L	0.0	2.0169	N.S.
As (Tot.) mg/L	3.81	2.0169	Cliff
Cd (Ext.) mg/L	0.0	2.0169	N.S.
Cu (Ext.) mg/L	1.55	2.0169	N.S.
Pb (Ext.) mg/L	0.0	2.0169	N.S.
Mn (Ext.) mg/L	0.64	2.0183	N.S.
Zn (Ext. Dir.) mg/L	5.10	2.0169	Cliff
Ca (Ext.) mg/L	1.29	2.0169	N.S.
Hg (Ext.) mg/L	2.58	2.0169	Cliff
Hg (Tot.) $\mu\text{g/L}$	3.65	2.0247	Trout

*N.S. - Difference not significant.

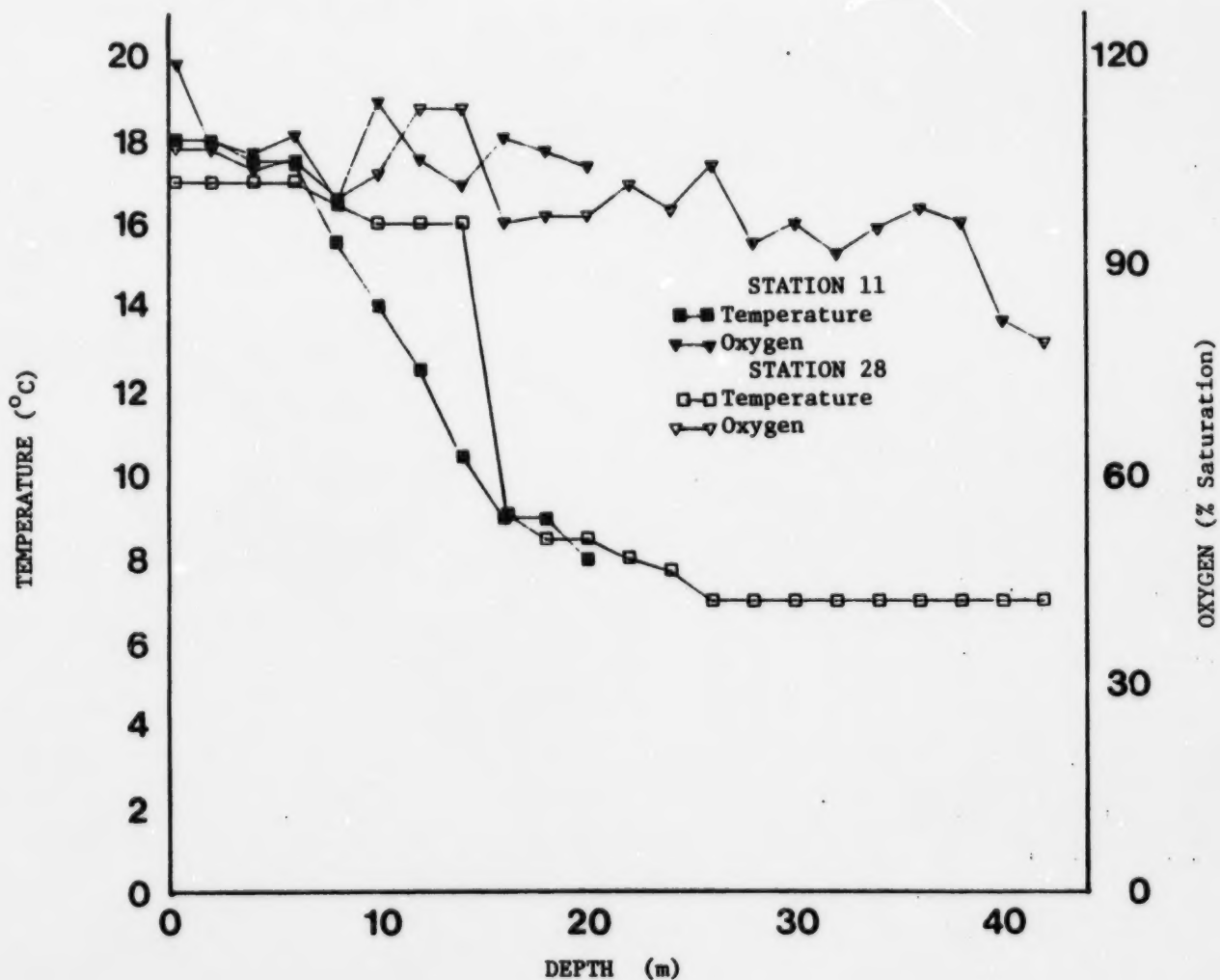


FIGURE 4: Profiles of Trout Lake Stations 11 and 28: Temperature and Dissolved Oxygen (July 14, 1981).

This was attributed to Trout Lake's larger surface area permitting greater wind action and hence a higher level of saturation.

Both Trout Lake and Cliff Lake were remarkably clear as mean turbidities were 1.3 and 1.2 Nephelometric turbidity units, respectively. Non-filterable residues from both were all less than the 5.0 mg/L detection limit.

The mean conductivity for Trout Lake (120 μ S/cm) was significantly smaller than the 124 μ S/cm mean for Cliff Lake. Although the 4 μ S/cm difference between means was within bounds attributable to analytical error (Sorba et al, 1980), the consistency of results for each lake suggested that the difference was real. (Calibration error was not implicated as all analyses were conducted in a single run. A. Jakalazik, pers. comm.). This implied that even though Trout Lake was a source of recharge to Cliff Lake, the latter was subject to additional ion loading.

Trout and Cliff Lakes are located in an area of the Precambrian Shield that is generally considered to be moderately sensitive to acid precipitation (Altshuller and McBean, 1979). Thus, pH values and buffering capabilities were of considerable interest. Mean pH values for both Trout and Cliff Lakes (7.70 and 7.79 units, respectively) were slightly alkaline. Both lakes appeared reasonably well buffered as total calcium carbonate alkalinities were 41.0 mg/L and 40.5 mg/L, respectively and bicarbonate alkalinities were 50.0 and 49.4 mg/L, respectively. The apparent significant differences between the mean alkalinities were considered an analytical artifact as the very minor unit differences were well within the bounds of analytical error (Sorba et al, 1980). Mean calcium concentrations were 16.0 and

15.0 mg/L, respectively and magnesium concentrations were 4.3 and 4.6 mg/L, respectively. These were also indicative of moderate buffering capability respecting sensitivity to acid precipitation.

Nutrient availability is essential for phytoplankton production and thus is a key indicator of trophic status. Mean total phosphorus (0.010 mg/L) and dissolved nitrogen (0.01 mg/L) concentrations in Trout Lake were consistent with an ultra-oligotrophic designation (Vollenweider, 1968). Similar mean nitrogen concentrations (0.01 mg/L) and a significantly greater mean total phosphorus concentration (0.04 mg/L) in Cliff Lake was more consistent with an oligotrophic designation (Ibid).

Metals and Cyanide

Both lakes are located in an area of the Precambrian Shield with very little overburden. Because of the near neutral pH, leaching of metals to the water column from surrounding parent material is of minor significance (Van Loon and Beamish, 1977). At the time of this study there were no direct anthropogenic sources of metals since development had not occurred prior to establishment of the Trout Lake Mine. However, both earlier studies (Van Loon and Beamish, 1977; Franzin et al, 1979) and later (Phillips et al, 1983) observed elevated levels of metals in the water column, local soils and on vegetation. These were attributed to aerial deposition from the Hudson Bay Mining and Smelting Company's smelter stack at Flin Flon (Van Loon and Beamish, 1977; Franzin et al, 1979; Phillips et al, 1983)).

Mean arsenic levels in Trout Lake (0.002 mg/L) were significantly lower than in Cliff Lake (0.004 mg/L). The significant difference (Table 3) between the two lakes may have been attributable to an apparent anomaly at station #1 of Cliff Lake. Although the station #1 value (0.010 mg/L) could have been eliminated using Dickson's Outlier Test, there did not appear to be sufficient justification for elimination of any parameter. Because of this uncertainty, differences in mean concentrations could not be ascribed to aerial deposition in the manner of Franzin et al (1979). Mean levels were below the objective levels recommended in both Canada and Manitoba drinking water quality guidelines*. Arsenic levels were also lower than levels encountered in other lakes within a similar geophysical setting such as Gods Lake and Wekusko Lake (Beck, 1982; Brown et al, 1980; respectively).

*Objectives for Canada and Manitoba
Drinking Water Quality Guidelines for Metals:.

	Canada(1) Maximum Acceptable Concentration	Canada(1) Objective Concentration	Manitoba(2) Objective Concentration
Arsenic mg/L	0.05	≤005	0.05
Cadmium mg/L	0.005	≤001	0.005
Copper mg/L	1.0	<1.0	1.0
Lead mg/L	0.05	≤001	0.05
Nickel mg/L			48.0 ³
Zinc mg/L	5.0	<5.0	5.0
Mercury mg/L	0.001	≤0.002	0.001

1. Federal-Provincial Working Group on Drinking Water, 1978.
2. Clean Environment Commission, 1979.
3. Clean Environment Commission, 1979. Varies with hardness (CaCO₃). Objective for maintenance of cold water aquatic life, cool water aquatic life and wildlife (CaCO₃ = 40.0 mg/L).

Cadmium was below the detection limit in all of the samples analysed. Other studies (Van Loon and Beamish, 1977) using detection limits lower than the present study's 0.005 mg/L range, found average cadmium concentrations of 0.4 µg/L in both lakes. Studies on aerial deposition have detected cadmium in precipitation samples (Phillips et al, 1983).

Average water column copper levels were 0.024 mg/L in Trout Lake and 0.032 mg/L in Cliff Lake. The difference was not significant and mean levels were well below the federal and provincial objective guidelines for drinking water (1.0 mg/L; see footnote, page 17). The observed levels were slightly higher than the 0.01 mg/L copper found by Van Loon and Beamish (1977). These levels also compared favorably with other lakes in similar geophysical settings such as Sherlett Lake and Wekusko Lake (Beck, 1983, Brown et al, 1980, respectively).

Lead was not detected in any water samples from either Trout Lake or Cliff Lake. Lead had been cited as one of the metals which is subject to aerial deposition in a relationship proportional to distance from the Flin Flon smelter (Franzin et al 1979; Phillips et al, 1983). Franzin et al (1979), for example, found deposition in snow to be over 20 mg/m² on Cliff Lake and 5 mg/m² on Trout Lake.

Mean concentrations of nickel were <0.007 mg/L and <0.006 mg/L, in Trout and Cliff Lakes, respectively. Because the frequency of detection appeared somewhat greater than that normally encountered (Water Standards and Studies, unpublished data), the present results may have been indicative of accelerated loading. However, anthropogenic loading by sources such as aerial deposition was not reported for the area by Van Loon and Beamish (1977).

Mean zinc concentrations in Cliff Lake (0.39 mg/L) were significantly greater than in Trout Lake (0.30 mg/L). Like copper, atmospheric deposition may have been the major source of zinc loading. This was consistent with earlier studies as Franzin et al (1979) found up to a ten fold difference in the amount of zinc deposited in snow on Cliff Lake as compared to Trout Lake. Mean deposition on Cliff Lake, for example, was up to 2403.0 mg/m². Van Loon and Beamish (1977) also found higher zinc levels in Cliff Lake in addition to a strong linear relationship between atmospheric fallout of zinc and distance from the smelter.

Mercury was not detected in any samples from Cliff Lake, but was detected in ten (33%) samples from Trout Lake. After samples had been analyzed, it was discovered that the sampler used on Trout Lake may have been contaminated with mercury. This was subsequently confirmed. Reported detected mercury levels were therefore considered invalid.

Cyanide was not detected at any station in Trout or Cliff Lakes.

Sediments

The results of sediment analyses for Trout and Cliff Lakes are detailed in Appendices 6 and 7, respectively. Summaries are presented in Table 4. Comparisons of mean metal concentrations are presented in Table 5.

Mean dry weight mercury concentrations in Cliff Lake sediments (1.22 µg/g) were approximately three times greater than

that of Trout Lake (0.402 $\mu\text{g/g}$). This difference was significant at $t = 0.05$ and may be indicative of differential loading. The case for differential loading was supported by sediment mercury levels in lakes of the Sherridon area. Camp Lake, which is subject to acid mine drainage, had mean mercury concentrations in sediments of 1.14 $\mu\text{g/g}$ whereas the unaffected control, Sherlett Lake, had mean mercury concentrations of only 0.32 $\mu\text{g/g}$ (Beck, 1983). Although apparently not examined by other investigators (Van Loon and Beamish, 1977; Franzin et al, 1979; Phillips et al, 1983), mercury may have had an anthropogenic source similar to that reported for copper and zinc.

Mean arsenic concentrations in Trout Lake sediments (175 $\mu\text{g/g}$) were significantly greater than that of Cliff Lake sediments (107 $\mu\text{g/g}$). This was contrary to water column results and to what might have been expected from reports of differential loading rates for arsenic (Franzin et al, 1979). Because mean arsenic concentrations in lake sediments unaffected by anthropogenic or natural sources are typically much lower (eg. 3.2 $\mu\text{g As/g}$ in Sherlett Lake; Beck, 1983), the inference was that elevated arsenic levels were primarily derived from underlying geological sources. Such an event was quite possible as Davies et al (1962) reported the occurrence of arsenopyrite in the area.

Mean cadmium concentrations in Cliff Lake sediments (17 $\mu\text{g/g}$) were significantly greater than that of Trout Lake (10 $\mu\text{g/g}$). This effect was consistent with the Franzin et al (1979) study of serial transport and differential loading of cadmium from the Flin Flon smelter. Loading was also indicated by the comparatively

TABLE 4: Summary of Sediment Analyses for Trout Lake and Cliff Lake.*

Parameter Statistic	Hg (wet) (µg/g)	Hg (dry) (µg/g)	As (µg/g)	Cd (µg/g)	Cu (µg/g)	Pb (µg/g)	Ni (µg/g)	Zn (µg/g)	Fe (%)	Mn (µg/g)	CW (µg/g)
<u>TROUT LAKE</u>											
X	0.136	0.402	175.	10.	318.	266.	67.	1502.	5.26	5432.	<1.
δ	0.101	0.374	119.5	4.8	170.7	146.0	39.0	958.8	2.47	10308.	0.0
HI	0.412	1.55	392.	26.	630.	499.	196.	2976.	12.5	39930.	<1.
Lo	0.0	0.0	15.	3.	69.	38.	11.	280.	0.85	109.	<1.
n	30	30	30	30	30	30	30	30	30	30	6
<u>CLIFF LAKE</u>											
X	0.34	1.22	107.	17.	620.	396.	44.	2922.	3.27	563.	<1.
δ	0.22	0.95	47.2	9.6	378.0	228.0	17.7	1759.	1.12	202.8	0.0
HI	0.726	2.76	183.	33.	1130.	665.	63.	5456.	4.44	908.	<1.
Lo	0.029	0.065	29.	3.	98.	57.	11.	384.	0.88	121.	<1.
n	15	15	15	15	15	15	15	15	15	15	3

Note: X = mean
 δ = standard deviation
 HI = highest value
 Lo = lowest value
 n = number of samples

TABLE 5: Comparison ($t \alpha = 0.05$) of Mean Sediment Metal Levels in Trout and Cliff Lakes.

<u>Metal</u>	<u>t</u>	<u>Lake with significantly greater concentrations</u>
Hg (wet)	3.42	Cliff
Hg (dry)	3.24	Cliff
As	2.74	Trout
Cd	2.43	Cliff
Cu	2.95	Cliff
Pb	2.02	Cliff
Ni	2.67	Trout
Zn	3.08	Cliff
Fe	3.71	Trout
Mn	2.59	Trout
CN	0.0	---

Critical Value ($t\alpha = 0.05$) 2.02

high mean cadmium concentrations observed versus that in a lake of a similar geophysical setting such as Sherlett (1.9 $\mu\text{g/g}$; Beck, 1983).

Cliff Lake mean copper concentrations (620 $\mu\text{g/g}$) were approximately double that of Trout Lake (318 $\mu\text{g/g}$). The difference was significant at $t = 0.05$. Because the difference between the lakes was not as great as might be expected if concentrations were solely the result of the aerial deposition reported by Van Loon and Beamish (1977), Franzin et al (1979) and Phillips et al (1983), a substantial portion of the copper present in lake sediments was considered attributable to adjacent orebodies of chalcopyrite (Davies et al, 1962).

The status of lead sediment concentrations was similar to that of copper. Mean lead concentrations in Cliff Lake sediments (396 $\mu\text{g/g}$) were significantly greater than that of Trout Lake (226 $\mu\text{g/g}$). However, the relatively small difference (absolute terms) between the lakes suggested that although lead was not detected in the water column, sediment results were attributable in part to the nearby orebodies reported by Davies et al (1962) and in part to aerial deposition as reported by Franzin et al (1979) and Phillips et al (1983).

Mean nickel concentrations in Trout Lake sediments (67 $\mu\text{g/g}$) were significantly greater than mean concentrations in Cliff Lake sediments (44 $\mu\text{g/g}$). Similar to water column results, sediment data were inconclusive and implied neither anthropogenic nor natural loading.

Mean zinc concentrations, like that of copper and lead, were significantly greater in the sediments of Cliff Lake (2922 $\mu\text{g/g}$) than in the sediments of Trout Lake (1502 $\mu\text{g/g}$). Compared to mean concentrations in sediments of an unimpacted lake such as Sherlett (189 $\mu\text{g/g}$; Beck, 1983), levels in both Trout and Cliff appeared indicative of loading. Like copper and lead, elevated zinc concentrations in sediments of Trout Lake and Cliff Lake were considered attributable to both anthropogenic (Franzin et al, 1979 and Phillips et al, 1983) and natural geological sources (Davis et al, 1962).

Both mean iron and manganese concentrations were significantly greater in Trout Lake sediments (5.26%, and 5432 $\mu\text{g/g}$; respectively) than in Cliff Lake sediments (3.27%, and 563 $\mu\text{g/g}$; respectively). Concentrations for both metals were considered within the range of normal background. The source of significant differences was attributed to varying trophic states (Hutchinson, 1957) and the associated variations due to nodule formation (Fairbridge, 1972).

Cyanide was not detected in any of the sediment samples.

Fish

A total of 127 fish were sampled, including 92 from Trout Lake and 35 from Cliff Lake. Analyses of the muscle tissue samples and general physical meristics are detailed in Appendices 8 and 9, respectively. Data are summarized in Tables 6 and 7 for Trout and Cliff Lake, respectively. Comparisons between the lakes ($t = 0.05$) are presented in Table 8.

Compared to work by Van Loon and Beamish (1977), the number of fish in Cliff Lake appeared greatly reduced by the time of the present study. Van Loon and Beamish (1977) reported a total catch of 440 fish with a combined catch per unit effort of 0.172 fish. This compared to a total of 35 fish and a combined catch per unit effort of 0.042 fish during the present study. However, direct comparison of effort and success between present and previous collections is not possible as the duration of sets and the size of mesh and nets in the earlier study were not published. Thus, some uncertainty surrounds the apparent fourfold decrease in Cliff Lake fish stocks.

Mean muscle tissue mercury concentrations in Trout Lake fish ranged from a high of 0.54 $\mu\text{g/g}$ in walleye to a low of 0.05 $\mu\text{g/g}$ in common sucker. Mean concentrations in northern pike (0.35 $\mu\text{g/g}$) and lake trout (0.24 $\mu\text{g/g}$) were somewhat lower than expected in view of the walleye concentrations. (Fish from similar levels commonly possess similar mercury concentrations.) Mean concentrations for Cliff Lake fish were generally lower than Trout Lake fish, with walleye at 0.39 $\mu\text{g/g}$, northern pike at 0.32 $\mu\text{g/g}$ and lake whitefish at 0.03 $\mu\text{g/g}$. Among the comparisons, only lake whitefish muscle tissue mercury concentrations differed significantly. Mean concentrations in lake whitefish (0.13 $\mu\text{g/g}$) from Trout Lake were significantly greater than those from Cliff Lake. Because differences in comparisons between lakes were not consistent (Table 8), it was inferred that differential loading of mercury was not occurring. This inference appeared to contradict assessment of the sediment results. Thus it could not be established that differential loading of mercury was occurring.

TABLE 6: Summary of General Physical Characteristics and Muscle Tissue Metal Levels, Trout Lake Fish.

Statistic ^a	Length (cm)	Weight (g)	Age (Yrs)	Muscle Tissue Metal Levels ($\mu\text{g/g}$ wet weight)						
				Hg	As	Cd	Cu	Pb	Ni	Zn
<u>WALLEYE (N = 11)</u>										
$\bar{X}$	54.72	1756	12.82	0.54	0.05	<0.1	0.38	0.53	<0.5	5.83
s	3.72	419.7	3.43	0.15	0.01	0.0	0.24	0.09	0.0	1.54
Hi	641	2900	17	0.68	0.07	<0.1	0.7	0.8	<0.5	9.5
Lo	492	1330	7	0.25	0.02	<0.1	<0.1	<0.5	<0.5	3.6
<u>NORTHERN PIKE (N = 20)</u>										
$\bar{X}$	54.76	1287.5	4.70	0.35	0.11	<0.1	0.27	<0.5	<0.5	4.75
s	10.34	1647.2	2.36	0.33	0.09	0.0	0.18	0.0	0.0	1.02
Hi	95.6	8220	14	1.66	0.31	<0.1	0.5	<0.5	<0.5	7.8
Lo	48.4	650	3	0.14	0.02	<0.1	<0.1	<0.5	<0.5	3.6
<u>LAKE WHITEFISH (N = 21)</u>										
$\bar{X}$	34.51	463.8	9.38	0.13	0.19	<0.1	0.24	<0.5	<0.5	3.99
s	6.68	315.2	3.97	0.05	0.19	0.0	0.12	0.0	0.0	0.69
Hi	44.8	1000	15	0.22	0.76	<0.1	0.4	<0.5	<0.5	5.7
Lo	24.8	100	5	0.06	0.03	<0.1	<0.1	<0.5	<0.5	3.1
<u>COMMON SUCKER (N = 19)</u>										
$\bar{X}$	47.79	1533.7	10.11	0.051	0.04	<0.1	0.36	<0.5	<0.5	6.19
s	3.78	410.4	2.40	0.026	0.017	0.0	0.28	0.0	0.0	2.35
Hi	53.2	2250	15	0.11	0.08	<0.1	1.0	0.5	<0.5	10.0
Lo	41.7	1040	6	<0.02	0.02	<0.1	<0.1	<0.5	<0.5	3.4
<u>LAKE TROUT (N = 21)</u>										
$\bar{X}$	49.73	1257.6	8.33	0.24	0.10	<0.1	0.36	<0.5	<0.5	4.60
s	5.07	347.9	4.70	0.15	0.05	0.0	0.20	0.0	0.0	0.98
Hi	58.6	1860	21	0.65	0.18	<0.1	0.9	0.5	<0.5	5.8
Lo	42.0	750	3	0.12	0.02	<0.1	<0.1	<0.5	<0.5	3.2

Note: $\bar{X}$ = mean
 s = standard deviation
 Hi = greatest value
 Lo = smallest value

TABLE 7: Summary of General Physical Meristics and Muscle Tissue Metal Levels, Cliff Lake Fish.

Statistic*	Length (cm)	Weight (g)	Age (Yrs)	Muscle Tissue Metal Levels (mg/g wet weight)						
				Hg (Wet)	As	Cd	Cu	Pb	Ni	Zn
<u>WALLEYE (N = 10)</u>										
$\bar{X}$	51.46	1586.0	12.80	0.39	0.09	<0.1	0.37	<0.5	0.53	5.45
s	6.56	563.1	3.85	0.18	0.03	0.0	0.09	0.0	0.09	1.38
Hi	62.0	2450.	19.	0.66	0.13	<0.1	0.5	<0.5	0.8	7.9
Lo	42.2	860.	5.	0.13	0.03	<0.1	0.3	<0.5	<0.5	3.8
<u>NORTHERN PIKE (N = 20)</u>										
$\bar{X}$	55.21	1277.5	4.95	0.32	0.08	<0.1	0.35	<0.5	0.52	6.16
s	8.03	1069.6	1.32	0.10	0.02	0.0	0.10	0.0	0.06	1.76
Hi	87.0	5760	9.	0.44	0.11	<0.1	0.5	<0.5	0.7	11.6
Lo	48.3	800	4.	0.19	0.04	<0.1	0.1	<0.5	<0.5	3.8
<u>LAKE WHITEFISH (N = 4)</u>										
$\bar{X}$	34.18	655	14.75	0.02	0.03	<0.1	0.45	<0.5	<0.5	5.33
s	2.98	126.9	4.19	0.0	0.01	0.0	0.13	0.0	0.0	1.09
Hi	37.7	800	21.	<0.02	0.05	<0.1	0.6	<0.5	<0.5	6.4
Lo	31.3	500	12.	<0.02	<0.02	<0.1	0.3	<0.5	<0.5	4.0

Note: $\bar{X}$ = mean
 s = standard deviation
 Hi = greatest value
 Lo = smallest value

TABLE 8: Comparison ($t\alpha = 0.05$) of General Physical Meristics and Muscle Tissue Metal Levels in Trout Lake and Cliff Lake Fish.

<u>Parameters</u>	Student "t" Values (Significantly greater by Lake)		
	<u>Walleye</u>	<u>Northern Pike</u>	<u>Lake Whitefish</u>
Length	1.38	0.15	0.16
Weight	0.78	0.02	2.04
Age	0.01	0.41	2.37 (Cliff L.)
Hg	2.06	0.39	10.08 (Trout L.)
As	4.02 (Cliff L.)	1.46	3.83 (Trout L.)
Cd	0.0	0.0	0.0
Cu	0.13	1.74	3.0 (Cliff L.)
Pb	1.11	0.0	0.0
Ni	1.11	1.49	0.0
Zn	0.60	3.10 (Cliff L.)	2.37 (Cliff L.)
Critical Value ($t\alpha = 0.05$)	2.09	2.02	2.07

Mean muscle tissue arsenic concentrations in Trout Lake fish ranged from a high of 0.19 $\mu\text{g/g}$ in lake whitefish to a low of 0.04 $\mu\text{g/g}$ in common sucker and 0.05 $\mu\text{g/g}$ in walleye. Northern pike and lake trout possessed intermediary levels of arsenic (0.11 $\mu\text{g/g}$, and 0.10 $\mu\text{g/g}$; respectively). Mean concentrations in Cliff Lake fish ranged from 0.09 $\mu\text{g/g}$ in walleye and 0.08 $\mu\text{g/g}$ in northern pike to 0.03 $\mu\text{g/g}$ in lake whitefish. Interlake comparisons provided contradictory results (Table 8). Cliff Lake walleye possessed significantly greater arsenic concentrations than did Trout Lake walleye. The reverse was true for lake whitefish. Thus, fish muscle tissue results failed to support the case for differential arsenic loading rates to the two lakes. However, arsenic loading appeared to be implicated as observed mean concentrations were generally well elevated over the trace levels typically encountered in fish from lakes such as Sherlett and Cold (Beck, 1983) and Wekusko (Brown et al, 1980). Because assessment of water, sediment and fish results failed to consistently implicate anthropogenic sources, it was concluded that arsenic levels in Trout Lake and Cliff Lake were primarily derived from underlying geological sources.

Cadmium was not detected in any of the fish sampled from either of Trout Lake or Cliff Lake. This neither supported nor detracted from the earlier suggestion that differential levels of cadmium in sediments were a result of deposition from smelter stack emissions.

Mean copper concentrations in Trout Lake fish showed little range between species. Mean concentrations observed ranged from 0.38 $\mu\text{g/g}$ in walleye to 0.24 $\mu\text{g/g}$ in lake whitefish. A similar situation was observed in fish from Cliff Lake, although the species were reversed. Maximum mean concentrations in Cliff Lake fish were found in whitefish (0.45 $\mu\text{g/g}$), whereas walleye (0.37 $\mu\text{g/g}$ and northern pike (0.35 $\mu\text{g/g}$) possessed lower concentrations. Among the interlake comparisons, only lake whitefish showed significantly different copper concentrations (Table 8). Lake whitefish from Cliff Lake possessed significantly greater copper concentrations than those from Trout Lake. This was considered supportive of the view that depositions from Flin Flon smelter stack emissions were loading copper to Cliff Lake at a greater rate than to Trout Lake.

Lead was detected in only two walleye (maximum, 0.8 $\mu\text{g/g}$), one lake trout (0.5 $\mu\text{g/g}$) and one common sucker (0.5 $\mu\text{g/g}$) from Trout Lake. Lead was not detected in any of the specimens from Cliff Lake. Minimal lead detections such as occurred during the present study are normal in unimpacted lakes and inferred that loading of lead to Trout Lake and Cliff Lake had not occurred. This compared favourably to water column results but was not supported by assessment of sediment analyses.

Nickel was not detected in any of the specimens from Trout Lake. However, it was detected in one walleye (0.8 $\mu\text{g/g}$) and two northern pike (both at 0.7 $\mu\text{g/g}$) from Cliff Lake. Interlake comparisons produced no significant differences. Minimal nickel detections are normal in unimpacted lakes and inferred that loading of

nickel to Trout Lake and Cliff Lake had not occurred. This assessment was consistent with those of the water column and sediment results.

Mean muscle tissue zinc concentrations in Trout Lake fish ranged from 6.19 $\mu\text{g/g}$ in common sucker to 3.99 $\mu\text{g/g}$ in lake whitefish. Mean concentrations in Cliff Lake fish ranged from 6.16 $\mu\text{g/g}$ in northern pike to 5.33 $\mu\text{g/g}$ in lake whitefish. Among the interlake comparisons, whitefish and northern pike from Cliff Lake possessed significantly greater muscle tissue zinc concentrations than did the comparable species from Trout Lake (Table 8). This inferred that Cliff Lake had received a greater loading of zinc than Trout Lake. The inference was consistent with assessments of both water column and sediment results and supports the respective conclusions of Van Loon and Beamish (1977), Franzin et al (1979) and Phillips et al (1983).

Benthos

Benthic organisms identified, calculations of densities ($\#/m^2$) and Zand's (1976) H' diversity are listed in Appendices 10 and 11 for Trout and Cliff Lakes, respectively. Relative composition by faunal groups and mean densities and diversities are presented in Tables 10 and 11.

A total of 558 benthic organisms were identified in the samples from Trout Lake (Appendix 10). This represented a mean density of 385 organisms per square metre. Pelecypods (fingernail clams) and chironomids (midges) dominated the benthic community as

respective relative abundances were 49.8% and 34.4%. The 0 - 15 metre depth zone was most densely colonized (580 organisms/m²) and was also the most diverse ($H' = 2.29$). Surprisingly, the 15 - 25 metre depth zone was least densely colonized (307 organisms/m²). However, the lowest diversity ($H' = 1.72$), as expected from the depth, was encountered in the 25 - 35 metre depth zone. Results were consistent with the earlier designation of ultra-oligotrophic status for Trout Lake.

A total of 351 organisms were identified in the samples from Cliff Lake (Appendix 11). The mean density of 474 organisms per square metre indicated a greater rate of productivity for Cliff Lake than for Trout Lake. The benthic community was dominated by chironomids (82%) and oligochaetes (annelid worms at 9.7%). The mean diversity ($H' = 1.90$) was only slightly larger than that of Trout Lake ($H' = 1.86$). Results were consistent with the earlier designation of oligotrophic status for Cliff Lake.

Phytoplankton

The relative distributions of phytoplankton in Trout Lake and Cliff Lake are presented in Appendix 12 and Appendix 13, respectively. The estimated surface area for each species is listed in Appendices 14 and 15 for Trout and Cliff Lakes, respectively.

Chrysophyta (Bacillariophyceae) dominated the Trout Lake phytoplankton, occupying about 68% of the total surface area (total surface area is the estimated area occupied by all species of

TABLE 9: Composition of Macroinvertebrate Fauna,
Trout Lake, 1981.

Faunal Group	Depth Zone							
	0-15m		15-25m		25-35m		Total	
	#	%	#	%	#	%	#	%
Ephemeroptera	1	0.7	2	0.8	-	-	3	0.5
Hemiptera								
Corixidae	1	0.7	-	-	-	-	1	0.2
Megaloptera	-	-	-	-	1	0.6	1	0.2
Coleoptera	-	-	1	0.4	-	-	1	0.2
Trichoptera	1	0.7	-	-	-	-	1	0.2
Diptera								
Culicidae	-	-	1	0.4	1	0.6	2	0.4
Chironomidae	39	27.9	64	25.9	89	52.0	192	34.4
Ceratopogonidae	1	0.7	2	0.8	-	-	3	0.5
Hydracarina	9	6.4	6	2.4	1	0.6	16	2.9
Pelecypoda	65	46.4	142	57.4	71	41.5	278	49.8
Oligochaeta	19	13.6	18	7.3	8	4.7	45	8.1
Nematoda	4	2.9	11	4.5	-	-	15	2.7
Total Organisms	140		247		171		558	
Number of Samples	5		17		8		30	
Mean Density (#/m ²)	580		307		430		385	
Mean Diversity (H')	2.29		1.80		1.72		1.86	

phytoplankton combined (Table 11). Stations 1 and 6 had the greatest diversity (11 species), and station 1 also contained the densest population in terms of surface area occupied.

Cliff Lake was also dominated by Chrysophyta (Bacillariophyceae), which occupied about 58% of the total surface area (Table 11). Station 9 had the greatest diversity (7 species) as well as the densest population.

TABLE 10: Composition of Macroinvertebrate Fauna,
Cliff Lake, 1981

Faunal Group	Depth Zone							
	0-6m		6-12m		12-18m		Total	
	#	%	#	%	#	%	#	%
Ephemeroptera	3	13.6	-	-	-	-	3	0.9
Diptera								
Culicidae	-	-	4	2.4	3	1.8	7	2.0
Chironomidae	16	72.7	130	78.8	142	86.1	288	82.1
Ceratopogonidae	-	-	1	0.6	-	-	1	0.3
Hydracarina	-	-	12	7.3	-	-	12	3.4
Oligochaeta	1	4.5	17	10.3	16	9.7	34	9.7
Nematoda	2	9.1	1	0.6	3	1.8	6	1.7
Total Organisms	22		165		164		351	
Number of Samples	1		6		8		15	
Mean Density (#/m ²)	420		548		425		474	
Mean Diversity (H')	3.10		1.99		1.68		1.90	

Table 11: Summary of Trout Lake and Cliff Lake Phytoplankton Data.

Taxa	TROUT LAKE			CLIFF LAKE		
	Number	Surface Area:		Number	Surface Area:	
		μ	%		μ	%
Cyanophyta	335	2600	8.37	190500	12400	34.76
Chlorophyta	65	4435	14.28	10	200	0.56
Chrysophyta (Bacillariophyceae)	155970	21200	68.25	1845	20525	57.53
Chrysophyta (Chrysophyceae)	67430	325	1.05	495	50	0.14
Pyrrophyta	5	2500	8.05	25	2500	7.01
Total	223805	31060	100.00	192875	35675	100.00

CONCLUSIONS

It was concluded that:

1. Trout Lake was best characterized by the term "ultra-oligotrophic" whereas Cliff Lake was best characterized by the term "oligotrophic".
2. Concentrations of copper and zinc in the water column, sediments and fish muscle tissue were greater in Cliff Lake than in Trout Lake due to depositions from the Flin Flon smelter stack emissions.
3. Elevated arsenic concentrations in the sediments and fish muscle tissue from Trout Lake and Cliff Lake were derived primarily from natural geological sources.
4. It could not be firmly established that lead, mercury and cadmium concentrations in the water, sediments and fish muscle tissue of Trout Lake and Cliff Lake were linked to anthropogenic sources.
5. Nickel had not been loaded to Trout Lake or Cliff Lake.

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APPENDIX 1(a): Random Sampling Depths for Trout Lake Stations.

STATION	DEPTH (m)	RANDOM %	SAMPLING DEPTH (m)
1	27.0	68	18.4
2	17.9	27	4.8
3	21.4	50	10.7
4	11.7	87	10.2
5	17.6	89	15.7
6	21.7	59	12.8
7	27.6	49	13.5
8	18.7	88	16.5
9	11.0	15	1.7
10	30.0	25	7.5
11	22.4	95	21.3
12	25.2	24	6.1
13	2.0	15	0.3
14	23.2	93	21.6
15	5.3	16	0.9
16	15.6	15	2.3
17	20.4	33	6.7
18	25.0	08	2.0
19	21.0	92	19.3
20	22.5	75	16.9
21	27.0	31	8.4
22	22.5	05	1.1
23	10.9	29	3.2
24	23.2	69	16.0
25	30.0	43	12.9
26	32.0	29	9.3
27	21.6	50	10.8
28	35.0	32	11.2
29	19.8	28	5.5
30	20.0	08	1.6

APPENDIX 1(b): Random Sampling Depths for Cliff Lake Stations.

STATION	DEPTH (m)	RANDOM %	SAMPLING DEPTH (m)
1	13.4	21	2.8
2	10.3	60	6.2
3	8.5	45	3.8
4	7.6	41	3.1
5	10.5	99	10.4
6	15.9	04	0.6
7	17.4	86	15.0
8	7.6	23	1.8
9	13.9	90	12.5
10	12.8	43	5.5
11	17.6	47	8.3
12	12.6	08	1.0
13	12.6	42	5.3
14	2.2	77	1.7
15	10.5	69	7.3

**APPENDIX 2a: Trout Lake Secchi Disc Transparencies and Phytoplankton
Random Sampling Depths.**

Station	Secchi Disc (m)	Random %	Sampling Depth (m)
1	5.0	68	6.8
2	5.0	27	2.7
3	5.0	50	5.0
4	5.0	87	8.7
5	5.0	89	8.9
6	5.0	59	5.9
7	5.0	49	4.9
8	5.0	88	8.8
9	5.25	15	1.6
10	4.0	25	2.0
11	5.0	95	9.5
12	5.0	24	2.4
13	Bottom	15	0.4
14	5.0	93	9.3
15	5.0	16	1.6
16	5.0	15	1.5
17	5.0	33	3.3
18	5.0	08	0.8
19	5.0	92	9.2
20	5.5	75	8.3
21	5.0	31	3.1
22	5.0	05	0.5
23	5.0	29	2.9
24	5.0	69	6.9
25	5.25	43	4.5
26	5.0	29	2.9
27	5.0	50	5.0
28	5.0	32	3.2
29	5.0	28	2.8
30	5.0	08	0.8

APPENDIX 2(b): Cliff Lake Secchi Disc Transparencies
and Phytoplankton Random Sampling Depths.

Station	Secchi Disc (m)	Random %	Sampling Depth (m)
1	3.5	21	1.5
2	3.1	60	3.7
3	3.0	45	2.7
4	3.2	41	2.5
5	3.5	99	7.0
6	3.4	04	0.3
7	3.5	86	6.0
8	3.5	23	1.6
9	3.0	90	5.4
10	3.3	43	2.8
11	3.4	47	3.6
12	3.1	08	0.5
13	3.5	42	2.9
14	2.2	77	3.3
15	3.3	69	4.5

APPENDIX 3: Trout Lake Temperature and Dissolved Oxygen Profiles, July 16, 1981.

Near Stn. 28				Near Stn. 11			
Depth(m)	D.O. (mg/L)	Temp. (°C)	Saturation (%)	Depth (m)	D.O. (mg/L)	Temp. (°C)	Saturation (%)
Surface	10.6	17.0	107	Surface	11.3	18.0	118
2	10.6	17.0	107	2	10.3	18.0	108
4	10.1	17.0	104	4	10.3	17.5	106
6	10.2	17.0	105	6	10.5	17.5	109
8	9.8	16.5	100	8	9.9	15.5	99
10	10.2	16.0	103	10	11.8	14.0	113
12	11.1	16.0	112	12	11.2	12.5	105
14	11.1	16.0	112	14	11.3	10.5	101
16	11.0	9.0	96	16	12.7	9.0	109
18	11.4	8.5	97	18	12.2	9.0	106
20	11.4	8.5	97	20-Bottom	12.4	8.0	104
22	12.0	8.0	101				
24	11.8	7.75	98				
26	12.7	7.0	104				
28	11.2	7.0	93				
30	11.7	7.0	96				
32	11.1	7.0	92				
34	11.6	7.0	95				
36	11.9	7.0	98				
38	11.7	7.0	96				
40	10.2	7.0	82				
Bottom	9.6	7.0	79				

APPENDIX 4: Trout Lake Water Physicochemistry, July 14, 1981.

PARAMETERS	STATIONS														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Field Temperature °C	18.0	19.0	16.0	14.0	11.0	12.0	11.0	14.0	19.0	16.0	10.0	16.0	19.0	17.0	19.0
Conductivity µS/cm	121.	120.	<5.0	<5.0	120.	120.	119.	120.	120.	121.	120.	121.	120.	119.	120.
Residue Rem Filtr. mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
pH (units)	7.65	7.95	7.70	7.70	7.60	7.50	7.50	7.60	7.90	7.80	7.60	7.80	7.70	7.40	7.60
Alkalinity (Total CaCO ₃) mg/L	40.8	42.0	40.8	42.0	41.2	40.8	40.2	41.2	41.0	41.0	41.0	40.5	40.8	40.5	40.5
Alkalinity (HCO ₃) mg/L	49.7	51.2	49.7	51.2	50.3	49.7	49.0	50.3	50.0	50.0	50.0	49.4	49.7	49.4	49.4
Alkalinity (CO ₃) mg/L	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alkalinity (OH) mg/L	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dissolved Oxygen mg/L	9.8	9.4	9.6	9.9	10.7	10.0	10.3	10.2	9.2	9.3	10.5	9.1	9.0	10.1	9.4
T.O.C. mg/L	11.0	11.0	11.0	11.0	11.0	12.0	11.5	12.0	13.5	12.5	11.5	12.5	12.0	13.0	13.0
T.I.C. mg/L	10.5	9.5	9.5	10.0	9.0	8.0	9.0	8.0	6.5	7.5	8.5	7.5	8.0	7.0	7.5
Turbidity NTU	1.0	1.0	1.0	1.0	1.0	0.75	1.0	0.85	2.5	1.0	1.0	1.0	1.0	8.5	1.0
Total Kjeldahl Nitrogen mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4
NO ₃ -NO ₂ -N (Diss.) mg/L	0.01	<0.01	0.01	<0.01	0.01	0.01	0.02	0.02	<0.01	0.03	0.02	<0.01	<0.01	<0.01	<0.01
P-Total mg/L	0.02	0.015	0.008	0.012	0.011	0.012	0.008	0.011	0.009	0.009	0.009	0.009	0.009	0.010	0.011
Cyanide (Tot.) mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cyanide (Free) mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
As (Tot.) mg/L	0.003	0.003	0.002	0.003	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.003	0.002	0.002	0.002
Cd (Ext.) mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cu (Ext.) mg/L	0.049	0.070	0.015	0.015	0.018	0.037	0.021	0.035	0.011	0.014	0.015	0.015	0.012	0.013	0.010
Pb (Ext.) mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Hg (Ext.) mg/L	0.023	<0.005	0.029	0.007	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005
Zn (Ext.) mg/L	0.31	0.31	0.30	0.30	0.30	0.31	0.31	0.31	0.30	0.30	0.31	0.28	0.28	0.31	0.28
Ca (Ext.) mg/L	15.	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.
Mg (Ext.) mg/L	5.	5.	5.	4.	5.	5.	4.	4.	4.3	4.	4.3	4.3	4.3	4.5	4.3
Ag (Ext.) mg/L	0.03	<0.02	<0.02	<0.02	0.04	<0.02	<0.02	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04

APPENDIX 4: Trout Lake Water Physicochemistry, July 14, 1981, (continued).

PARAMETERS	STATIONS														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Field Temperature °C	19.0	17.0	17.0	10.5	10.0	15.0	19.0	19.0	15.0	19.0	16.0	16.0	13.0	19.0	19.0
Conductivity µS/cm	120.	120.	120.	149.	121.	121.	120.	121.	120.	120.	120.	121.	120.	121.	121.
Residue Non Filt. mg/L	<5.0	<5.0	<5.0	—	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
pH (units)	7.60	7.70	7.80	9.50	7.50	7.70	7.80	7.80	7.55	7.60	7.65	7.65	7.70	7.85	7.90
Alkalinity (Total CaCO ₃) mg/L	41.0	41.0	41.2	57.	41.0	40.8	41.8	40.5	41.0	41.2	41.8	41.8	42.0	40.2	40.8
Alkalinity (HCO ₃) mg/L	50.0	50.0	50.3	40.3	50.0	49.7	50.9	49.4	50.0	50.3	50.3	49.7	51.2	49.1	49.7
Alkalinity (CO ₃) mg/L	0.0	0.0	0.0	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alkalinity (OH) mg/L	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dissolved Oxygen mg/L	9.4	9.5	9.1	10.7	10.5	9.7	9.4	9.5	10.6	10.4	10.0	9.8	10.3	9.5	9.2
T.O.C. mg/L	12.5	13.5	11.5	11.5	12.0	11.5	11.0	11.5	10.0	10.0	10.0	10.5	10.0	11.5	11.0
T.I.C. mg/L	7.0	6.5	8.5	8.0	8.0	8.5	9.0	8.5	10.0	10.0	9.5	9.5	10.0	10.0	9.5
Turbidity NTU	1.0	1.0	1.0	1.0	1.0	1.5	1.0	1.0	1.0	1.0	1.5	1.5	1.0	1.0	1.0
Total Kjeldhal Nitrogen mg/L	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
NO ₃ -NO ₂ -N (Diss.) mg/L	<0.01	<0.01	<0.01	0.03	0.03	<0.01	0.03	<0.01	0.02	0.02	<0.01	<0.01	0.01	0.01	<0.01
P-Total mg/L	0.010	0.011	0.010	0.009	0.008	0.012	0.008	0.009	0.01	0.008	0.007	0.010	0.009	0.010	0.009
Cyanide (Tot.) mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cyanide (Free) mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
As (Tot.) mg/L	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
Cd (Ext.) mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cu (Ext.) mg/L	0.021	0.015	0.016	0.010	0.016	0.034	0.014	0.010	0.040	0.019	0.015	0.075	0.034	0.045	0.015
Pb (Ext.) mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Mn (Ext.) mg/L	<0.005	0.025	0.005	0.081	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zn (Ext.) mg/L	0.28	0.30	0.28	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.30	0.30	0.30	<0.005	0.009
Ca (Ext.) mg/L	13.	15.	15.	15.	15.	15.	13.	18.	20.	23.	23.	23.	23.	0.30	0.30
Mg (Ext.) mg/L	4.5	4.3	4.5	4.3	4.5	4.5	4.5	3.8	3.8	3.8	3.8	3.8	3.8	3.5	3.5
Mg (Tot.) µg/L	<0.02	<0.02	0.07	<0.02	<0.02	<0.02	0.04	0.03	0.04	0.06	<0.02	<0.02	<0.02	0.06	<0.02

APPENDIX 5: Cliff Lake Water Physicochemistry, July 11, 1981.

PARAMETERS	STATIONS														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Field Temperature °C	19.0	19.0	19.0	19.0	14.0	19.0	11.0	19.0	11.0	19.0	16.0	19.0	19.0	19.0	18.0
Conductivity µS/cm	124.	123.	124.	125.	123.	123.	123.	123.	123.	124.	124.	124.	124.	124.	123.
Residue Non Filt. mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
pH (units)	8.00	7.90	7.95	7.95	7.60	8.0	7.15	7.90	7.30	7.95	7.70	7.80	7.95	7.90	7.80
Alkalinity (Total CaCO ₃) mg/L	40.8	40.5	40.5	40.8	40.0	40.5	40.8	40.5	40.5	40.2	40.5	40.8	40.2	40.5	41.0
Alkalinity (HCO ₃) mg/L	49.7	49.4	49.4	49.7	48.8	49.4	49.7	49.4	49.4	49.1	49.4	49.4	49.1	49.4	50.0
Alkalinity (CO ₃) mg/L	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alkalinity (OH) mg/L	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dissolved Oxygen mg/L	8.7	8.7	8.8	8.7	9.4	8.6	8.0	8.6	8.4	8.7	8.6	8.9	8.8	8.9	8.1
T.O.C. mg/L	10.0	10.5	11.0	12.5	11.5	12.0	12.5	12.5	11.5	11.5	11.0	11.5	11.5	12.0	11.5
T.I.C. mg/L	10.0	9.5	8.5	7.0	8.5	8.0	8.0	8.0	9.0	8.5	9.5	8.0	8.0	8.5	9.0
Turbidity NTU	1.0	1.0	1.0	1.5	1.0	1.0	1.0	1.0	1.5	1.0	1.5	1.5	1.5	1.0	0.9
Total Kjeldhal Nitrogen mg/L	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
NO ₃ -NO ₂ -N (Diss.) mg/L	<0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01	<0.01	0.01	<0.01	0.01
P-Total mg/L	0.021	0.011	0.011	0.013	0.014	0.009	0.018	0.017	0.016	0.019	0.013	0.017	0.012	0.011	0.012
Cyanide (Tot.) mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cyanide (Free) mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
As (Tot.) mg/L	0.010	0.005	0.003	0.004	0.003	0.003	0.004	0.002	0.003	0.002	0.004	0.003	0.003	0.003	0.002
Cd (Ext.) mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cu (Ext.) mg/L	0.026	0.031	0.034	0.031	0.036	0.023	0.032	0.015	0.023	0.035	0.021	0.07	0.067	0.012	0.026
Pb (Ext.) mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Mn (Ext.) mg/L	0.008	<0.005	<0.005	<0.005	0.015	<0.005	0.015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zn (Ext.) mg/L	0.34	0.36	0.36	0.39	0.43	0.36	0.57	0.34	0.53	0.36	0.41	0.37	0.37	0.36	0.36
Ca (Ext.) mg/L	18.	15.	15.	15.	15.	15.	15.	15.	15.	15.	14.	13.	15.	15.	15.
Mg (Ext.) mg/L	5.	5.	4.5	4.5	4.5	4.3	4.3	4.3	4.3	4.5	5.	4.3	5.	5.	5.
Mg (Tot.) µg/L	<0.02	—	—	—	<0.02	<0.02	<0.02	—	<0.02	<0.02	<0.02	—	<0.02	<0.02	<0.02

APPENDIX 6: Trout Lake Sediment Analysis, 1981.

Parameter Station	Hg (wet) (µg/g)	Hg (dry) (µg/g)	As (µg/g)	Cd (µg/g)	Cu (µg/g)	Pb (µg/g)	Ni (µg/g)	Zn (µg/g)	Fe (%)	Mn (µg/g)	CN (µg/g)
1	0.192	0.440	158.	7.	310.	230.	47.	1150.	3.3	800.	
2	0.126	0.336	183.	12.	320.	220.	73.	1250.	4.31	1656.	
3	0.043	0.084	167.	9.	170.	150.	152.	950.	6.49	1822.	
4	0.197	0.592	383.	10.	420.	380.	58.	1500.	5.90	938.	
5	0.051	0.104	24.	3.	80.	70.	21.	280.	1.77	323.	<1.
6	0.046	0.124	126.	5.	130.	130.	44.	490.	3.89	766.	
7	0.402	1.55	513.	16.	567.	499.	56.	2480.	5.19	908.	
8	0.120	0.329	96.	5.	126.	57.	63.	570.	4.44	871.	
9	0.192	0.476	102.	8.	309.	257.	52.	967.	4.31	992.	
10	0.234	0.765	297.	14.	630.	466.	52.	2670.	5.25	1089.	<1.
11	0.176	0.529	302.	13.	397.	380.	56.	1612.	5.63	4296.	
12	0.169	0.481	133.	10.	340.	304.	56.	1240.	4.94	1041.	
13	0.075	0.126	26.	5.	95.	38.	11.	508.	0.85	109.	
14	0.122	0.386	167.	12.	397.	361.	56.	1920.	5.31	4235.	
15	0.128	0.284	62.	5.	151.	95.	21.	794.	1.63	236.	<1.
16	0.134	0.412	392.	26.	416.	342.	105.	2666.	12.5	39930.	
17	0.086	0.263	158.	13.	441.	409.	56.	1612.	4.94	944.	
18	0.104	0.267	53.	7.	239.	228.	56.	818.	4.81	678.	
19	0.178	0.706	247.	14.	447.	418.	56.	1920.	10.0	4235.	
20	0.092	0.179	142.	12.	195.	171.	196.	1029.	9.69	33880.	<1.
21	0.085	0.173	137.	7.	123.	152.	112.	552.	9.69	24200.	
22	0.078	0.252	147.	14.	498.	399.	56.	2790.	5.06	1815.	
23	0.124	0.238	125.	9.	176.	152.	140.	980.	5.31	22990.	
24	0.412	1.48	150.	14.	567.	456.	56.	2902.	5.44	1815.	<1.
25	0.134	0.410	198.	8.	321.	266.	56.	1550.	4.88	1077.	
26	0.305	0.869	200.	12.	466.	428.	56.	2356.	4.69	532.	
27	0.011	0.018	18.	3.	88.	57.	88.	372.	4.81	2662.	
28	0.026	0.097	333.	13.	510.	409.	56.	2976.	4.81	1936.	
29	0.047	0.078	15.	4.	69.	57.	46.	298.	2.63	4356.	
30	0.0	0.0	208.	13.	529.	390.	56.	2852	5.19	1815.	<1.

APPENDIX 7: Cliff Lake Sediment Analysis, 1981.

Parameter Station	Hg (wet) (µg/g)	Hg (dry) (µg/g)	As (µg/g)	Cd µg/g)	Cu (µg/g)	Pb (µg/g)	Ni (µg/g)	Zn (µg/g)	Fe (%)	Mn (µg/g)	CN (µg/g)
1	0.338	1.11	97.	14.	485.	323.	35.	1984.	2.75	496.	
2	0.112	0.213	55.	8.	227.	181.	21.	1042.	1.94	411.	
3	0.152	0.293	97.	8.	334.	247.	35.	1364.	2.94	678.	
4	0.614	1.62	142.	23.	1010.	618.	35.	3844.	3.00	750.	
5	0.429	1.63	155.	21.	760.	494.	56.	3720.	4.19	738.	<1.
6	0.235	0.932	152.	25.	880.	589.	63.	5084.	4.06	617.	
7	0.726	2.76	121.	26.	1100.	627.	60.	5456.	4.13	532.	
8	0.420	1.25	133.	12.	441.	333.	35.	2232.	2.63	448.	
9	0.434	1.75	100.	20.	790.	513.	63.	3968.	4.13	496.	<1.
10	0.050	0.065	51.	3.	98.	67.	21.	384.	1.63	254.	
11	0.029	0.114	155.	3.	110.	57.	63.	720.	3.75	678.	
12	0.292	1.15	42.	33.	1010.	665.	56.	3968.	4.31	908.	
13	0.691	2.55	91.	26.	1130.	637.	56.	4960.	4.44	605.	
14	0.177	0.274	29.	5.	129.	57.	11.	893.	0.88	121.	
15	0.441	1.60	183.	21.	790.	532.	56.	4216.	4.25	714.	<1.

APPENDIX 8(a): General Meristics and Muscle Tissue Metal Concentrations,
Trout Lake Walleye, 1981.

Length (cm)	Weight (g)	Sex	Age (Yrs)	Muscle Tissue Metal Levels (µg/g)						
				Hg	As	Cd	Cu	Pb	Ni	Zn
641	2900	F	17	0.56	0.06	<0.1	0.1	0.5	<0.5	6.3
526	1620	M	12	0.54	0.04	<0.1	0.6	<0.5	<0.5	6.8
492	1600	F	7	0.25	0.04	<0.1	<0.1	<0.5	<0.5	3.6
524	1570	F	8	0.25	0.04	<0.1	0.4	<0.5	<0.5	5.8
542	1330	M	12	0.66	0.05	<0.1	0.5	<0.5	<0.5	5.5
570	2040	M	11	0.68	0.07	<0.1	<0.1	<0.5	<0.5	4.2
449	1800	M	11	0.54	0.03	<0.1	0.5	<0.5	<0.5	5.2
550	1720	M	16	0.60	0.02	<0.1	0.1	<0.5	<0.5	5.2
530	1560	M	15	0.68	0.06	<0.1	0.7	0.8	<0.5	6.5
539	1680	M	16	0.56	0.06	<0.1	0.6	<0.5	<0.5	9.5
556	1500	M	16	0.65	0.05	<0.1	0.5	<0.5	<0.5	5.5

APPENDIX 8(b): General Meristics and Muscle Tissue Metal Concentrations,
Trout Lake Northern Pike, 1981.

Length (cm)	Weight (g)	Sex	Age (Yrs)	Muscle Tissue Metal Levels (µg/g)						
				Hg	As	Cd	Cu	Pb	Ni	Zn
552	940	M	4	0.34	0.05	<0.1	0.1	<0.5	<0.5	3.9
502	760	F	4	0.19	0.08	<0.1	<0.1	<0.5	<0.5	3.9
652	1680	F	6	0.60	0.05	<0.1	0.5	<0.5	<0.5	4.7
533	970	F	6	0.30	0.29	<0.1	<0.1	<0.5	<0.5	4.6
536	800	F	4	0.35	0.30	<0.1	0.1	<0.5	<0.5	5.3
528	900	M	5	0.26	0.13	<0.1	0.1	<0.5	<0.5	4.3
490	750	M	4	0.14	0.06	<0.1	0.5	<0.5	<0.5	7.8
510	800	F	4	0.19	0.06	<0.1	0.2	<0.5	<0.5	5.0
506	810	F	4	0.20	0.06	<0.1	0.2	<0.5	<0.5	6.8
536	1150	M	4	0.34	0.02	<0.1	0.2	<0.5	<0.5	4.8
492	650	F	4	0.32	0.10	<0.1	0.3	<0.5	<0.5	4.7
484	840	M	3	0.18	0.10	<0.1	<0.1	<0.5	<0.5	5.5
557	1100	M	4	0.30	0.12	<0.1	<0.1	<0.5	<0.5	4.5
490	790	M	4	0.17	0.05	<0.1	0.4	<0.5	<0.5	4.0
549	1080	M	6	0.38	0.20	<0.1	0.2	<0.5	<0.5	3.6
552	1070	F	4	0.44	0.07	<0.1	0.5	<0.5	<0.5	4.0
528	900	F	3	0.18	0.07	<0.1	0.1	<0.5	<0.5	3.7
484	700	F	3	0.21	0.08	<0.1	0.5	<0.5	<0.5	4.6
956	8220	F	14	1.66	0.09	<0.1	0.5	<0.5	<0.5	4.7
515	840	M	4	0.24	0.31	<0.1	0.5	<0.5	<0.5	4.6

APPENDIX 8(c): General Meristics and Muscle Tissue Metal Concentrations,
Trout Lake Whitefish, 1981.

Length (cm)	Weight (g)	Sex	Age (Yrs)	Muscle Tissue Metal Levels (µg/g)						
				Hg	As	Cd	Cu	Pb	Ni	Zn
260	170	F	9	0.08	0.04	<0.1	0.4	<0.5	<0.5	3.6
260	170	F	6	0.08	0.05	<0.1	<0.1	<0.5	<0.5	3.6
362	400	F	7	0.13	0.76	<0.1	0.2	<0.5	<0.5	3.5
344	390	F	8	0.06	0.21	<0.1	0.2	<0.5	<0.5	3.1
326	300	F	6	0.10	0.26	<0.1	0.2	<0.5	<0.5	4.4
328	200	M	6	0.08	0.36	<0.1	0.2	<0.5	<0.5	3.3
448	1000	F	15	0.20	0.06	<0.1	0.4	<0.5	<0.5	4.4
362	540	M	7	0.06	0.22	<0.1	0.2	<0.5	<0.5	3.5
320	300	F	10	0.13	0.41	<0.1	0.2	<0.5	<0.5	3.8
240	100	M	5	0.11	0.04	<0.1	0.2	<0.5	<0.5	3.8
300	130	M	5	0.08	0.03	<0.1	0.4	<0.5	<0.5	4.3
255	120	M	5	0.10	0.05	<0.1	0.2	<0.5	<0.5	4.9
406	760	M	11	0.19	0.16	<0.1	0.2	<0.5	<0.5	3.5
418	800	M	13	0.15	0.07	<0.1	<0.1	<0.5	<0.5	4.4
420	980	F	13	0.16	0.08	<0.1	0.2	<0.5	<0.5	3.3
396	680	F	10	0.18	0.05	<0.1	0.2	<0.5	<0.5	5.1
417	880	F	11	0.22	0.33	<0.1	<0.1	<0.5	<0.5	3.2
384	650	M	14	0.15	0.51	<0.1	0.4	<0.5	<0.5	3.7
430	820	F	10	0.20	0.09	<0.1	0.4	<0.5	<0.5	4.3
323	250	F	6	0.12	0.08	<0.1	0.4	<0.5	<0.5	5.7
248	100	F	6	0.09	0.06	<0.1	0.4	<0.5	<0.5	4.4

APPENDIX 8(d): General Meristics and Muscle Tissue Metal Concentrations,
Trout Lake White Sucker, 1981.

Length (cm)	Weight (g)	Sex	Age (Yrs)	Muscle Tissue Metal Levels (µg/g)						
				Hg	As	Cd	Cu	Pb	Ni	Zn
417	1040	M	7	0.02	0.06	<0.1	0.6	<0.5	<0.5	5.2
446	1160	M	9	0.03	0.05	<0.1	<0.1	<0.5	<0.5	4.0
470	1310	F	9	0.02	0.06	<0.1	0.8	<0.5	<0.5	9.2
461	1300	M	12	0.10	0.04	<0.1	1.0	<0.5	<0.5	9.9
430	1060	M	9	0.05	0.04	<0.1	0.1	<0.5	<0.5	5.2
442	1150	M	11	0.05	0.07	<0.1	0.5	0.5	<0.5	6.8
442	1150	M	11	0.05	0.06	<0.1	0.2	<0.5	<0.5	6.8
523	2120	F	9	0.07	0.04	<0.1	0.6	<0.5	<0.5	9.4
478	1460	F	10	0.07	0.04	<0.1	0.6	<0.5	<0.5	7.0
426	1180	F	8	<0.02	0.05	<0.1	0.6	<0.5	<0.5	10.0
464	1210	F	8	0.02	0.03	<0.1	0.2	<0.5	<0.5	4.1
474	1400	F	6	0.04	0.02	<0.1	0.1	<0.5	<0.5	3.6
532	2250	F	11	0.06	0.02	<0.1	0.1	<0.5	<0.5	5.0
500	1820	F	9	0.04	0.04	<0.1	0.2	<0.5	<0.5	3.5
515	1820	F	15	0.08	0.03	<0.1	0.6	<0.5	<0.5	8.1
512	1810	F	10	0.04	0.08	<0.1	0.1	<0.5	<0.5	4.4
530	2150	F	13	0.05	0.03	<0.1	0.1	<0.5	<0.5	3.4
518	2050	F	15	0.11	0.03	<0.1	0.2	<0.5	<0.5	3.9
500	1700	F	10	0.04	0.03	<0.1	0.2	<0.5	<0.5	8.1

APPENDIX 8(e): General Meristics and Muscle Tissue Metal Concentrations,
Trout Lake Lake Trout, 1981.

Length (cm)	Weight (g)	Sex	Age (Yrs)	Muscle Tissue Metal Levels (µg/g)						
				Hg	As	Cd	Cu	Pb	Ni	Zn
495	1560	M	8	0.21	0.17	<0.1	0.2	<0.5	<0.5	4.6
586	1850	F	21	0.55	0.11	<0.1	0.2	<0.5	<0.5	4.4
473	1140	M	6	0.13	0.10	<0.1	0.2	<0.5	<0.5	3.2
570	1750	F	18	0.52	0.06	<0.1	0.6	<0.5	<0.5	4.3
503	1370	M	11	0.25	0.09	<0.1	0.2	<0.5	<0.5	4.4
477	1000	M	6	0.17	0.10	<0.1	0.6	<0.5	<0.5	5.0
529	1380	F	15	0.65	0.13	<0.1	<0.1	<0.5	<0.5	4.2
564	1860	M	7	0.23	0.15	<0.1	0.4	<0.5	<0.5	4.0
442	830	M	5	0.13	0.05	<0.1	0.4	<0.5	<0.5	5.0
464	980	F	4	0.17	0.15	<0.1	0.4	<0.5	<0.5	4.7
454	1000	M	8	0.12	0.09	<0.1	0.6	<0.5	<0.5	5.0
420	750	M	3	0.21	0.06	<0.1	0.9	<0.5	<0.5	3.2
500	1350	M	5	0.12	0.05	<0.1	0.2	<0.5	<0.5	3.2
430	780	M	4	0.13	0.04	<0.1	0.3	<0.5	<0.5	4.9
422	800	F	5	0.15	0.11	<0.1	0.2	<0.5	<0.5	4.0
534	1350	M	8	0.26	0.13	<0.1	0.4	<0.5	<0.5	5.8
484	1100	F	6	0.18	0.02	<0.1	0.2	<0.5	<0.5	4.0
520	1520	M	9	0.24	0.06	<0.1	0.2	<0.5	<0.5	4.9
473	1140	M	6	0.19	0.15	<0.1	0.2	<0.5	<0.5	3.9
530	1300	M	8	0.21	0.18	<0.1	0.4	<0.5	<0.5	5.4
574	1600	F	12	0.14	0.02	<0.1	0.6	0.5	<0.5	7.6

APPENDIX 9(a): General Meristics and Muscle Tissue Metal Concentrations,
Cliff Lake Walleye, 1981.

Length (cm)	Weight (g)	Sex	Age (Yrs)	Muscle Tissue Metal Levels (µg/g)						
				Hg	As	Cd	Cu	Pb	Ni	Zn
51.5	1550	F	12	0.31	0.10	<0.1	0.3	<0.5	<0.5	5.3
52.6	1700	F	12	0.36	0.10	<0.1	0.5	<0.5	<0.5	6.0
47.7	1250	M	19	0.60	0.08	<0.1	0.5	<0.5	<0.5	7.9
62.0	2450	F	17	0.52	0.12	<0.1	0.3	<0.5	<0.5	3.8
45.0	1000	F	10	0.13	0.03	<0.1	0.3	<0.5	0.8	6.0
44.1	980	F	11	0.27	0.07	<0.1	0.3	<0.5	<0.5	4.7
42.2	860	F	5	0.15	0.05	<0.1	0.3	<0.5	<0.5	7.4
55.2	1690	F	14	0.41	0.13	<0.1	0.4	<0.5	<0.5	3.9
57.3	2160	F	14	0.66	0.09	<0.1	0.3	<0.5	<0.5	4.8
57.0	2220	F	14	0.48	0.12	<0.1	0.5	<0.5	<0.5	4.7

APPENDIX 9(b): General Meristics and Muscle Tissue Metal Concentrations,
Cliff Lake Northern Pike, 1981.

Length (cm)	Weight (g)	Sex	Age (Yrs)	Muscle Tissue Metal Levels (ug/g)						
				Hg	As	Cd	Cu	Pb	Ni	Zn
52.1	1100	M	4	0.21	0.07	<0.1	0.3	<0.5	<0.5	6.6
56.9	1060	M	6	0.41	0.09	<0.1	0.3	<0.5	<0.5	7.5
53.6	1090	F	4	0.25	0.09	<0.1	0.5	<0.5	<0.5	4.6
53.7	1000	F	4	0.19	0.08	<0.1	0.3	<0.5	0.7	5.2
50.0	1010	M	4	0.22	0.06	<0.1	0.3	<0.5	<0.5	5.1
48.3	820	M	4	0.23	0.05	<0.1	0.4	<0.5	<0.5	5.5
50.5	840	F	4	0.20	0.08	<0.1	0.3	<0.5	0.7	4.6
57.3	1080	F	6	0.44	0.11	<0.1	0.3	<0.5	<0.5	8.2
49.9	820	F	4	0.24	0.08	<0.1	0.3	<0.5	<0.5	11.6
48.7	1560	M	6	0.31	0.09	<0.1	0.5	<0.5	<0.5	7.8
53.5	900	F	4	0.41	0.07	<0.1	0.3	<0.5	<0.5	6.2
54.5	1260	M	4	0.30	0.08	<0.1	0.3	<0.5	<0.5	6.0
55.0	980	F	5	0.39	0.08	<0.1	0.4	<0.5	<0.5	7.7
56.7	1160	F	5	0.44	0.09	<0.1	0.1	<0.5	<0.5	4.9
51.5	800	M	6	0.39	0.10	<0.1	0.3	<0.5	<0.5	5.7
56.4	1100	M	4	0.40	0.06	<0.1	0.5	<0.5	<0.5	5.2
56.1	1170	F	6	0.39	0.08	<0.1	0.5	<0.5	<0.5	3.8
55.3	1060	F	6	0.42	0.09	<0.1	0.3	<0.5	<0.5	5.1
57.2	980	F	4	0.42	0.05	<0.1	0.4	<0.5	<0.5	6.6
87.0	5760	F	9	0.19	0.04	<0.1	0.4	<0.5	<0.5	5.2

APPENDIX 9(c): General Meristics and Muscle Tissue Metal Concentrations,
Cliff Lake Whitefish, 1981.

Length (cm)	Weight (g)	Sex	Age (Yrs)	Muscle Tissue Metal Levels (µg/g)					
				Hg	As	Cd	Cu	Pb	Mi Zn
35.4	700	M	13	<0.02	0.03	<0.1	0.6	<0.5	<0.5 4.9
37.7	800	M	13	<0.02	0.05	<0.1	0.4	<0.5	<0.5 6.0
32.3	620	F	21	<0.02	<0.02	<0.1	0.3	<0.5	<0.5 4.0
31.3	500	M	12	<0.02	<0.02	<0.1	0.5	<0.5	<0.5 6.4

APPENDIX 9(d): General Meristics and Muscle Tissue Metal Concentrations,
Cliff Lake White Sucker, 1981.

Length (cm)	Weight (g)	Sex	Age (Yrs)	Muscle Tissue Metal Levels (µg/g)					
				Hg	As	Cd	Cu	Pb	Mi Zn
42.8	1100	M	7	0.10	<0.02	<0.1	0.4	<0.5	<0.5 6.9

[illegible]

APPENDIX II: Distribution of Benthos, Cliff Lake, July, 1981

TAXA / STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
Ephemeroptera																
<i>Caenis</i> sp.			2											3		3
Diptera																
Culicidae																
<i>Chaoborus</i> sp.			3				2		1						1	7
Chironomidae																
<i>Procladius</i> sp.	24	6	8	12	12	4	9	8	8	2	13	4	12	1	12	135
<i>Chironomus</i> sp.					4	6	1	3	1		10	15	2	5	4	46
<i>Polypedium</i> sp.	13				1									2		19
<i>Cryptochironomus</i> sp.														1		2
<i>Parachironomus</i> sp.					2											2
<i>Endochironomus</i> sp.					21											21
<i>Phaenopsectra</i> sp.								18	1				1	3	8	54
<i>Pagastiella</i> sp.	8			1										1		9
<i>Paracladopelma</i> sp.				1												1
<i>Stictochironomus</i> sp.	4	1														5
<i>Glyptotendipes</i> sp.		2											1		1	2
<i>Micropectus</i> sp.	3	2												3		7
<i>Procladius</i> sp.																3
<i>Nannochloris</i> sp.																1
Ceratopogonidae																
Hydracarina																
<i>Hygrobatas</i> sp.			8													8
<i>Hygrobatas neoecotoporus</i>			1													1
<i>Lebertia</i> (<i>Hexalebertia</i>) <i>stellae</i>																1
<i>Limnesia maculata</i>																1
<i>Piona</i> ? <i>rotunda</i>																1
Oligochaeta	1															2
Naididae																1
<i>Stylaria</i> sp.					1				1							2
Imm. Tubif. with hair setae														1		1
<i>Pelocolex</i> sp.					13	2	1				2	2				20
Imm. Tubif. without hair setae					2	2	2				2					6
<i>Limnodrilus</i>					5	4	2		2		2	4				2
Enchytraeidae											1	2				19
Unidentified fragment														2		6
Nematoda																
TOTAL	53	17	19	19	61	19	17	30	14	2	30	27	16	22	26	372
R ²	2.05	2.54	1.62	1.98	2.54	2.38	2.06	1.45	1.95	0.00	2.00	1.84	1.19	3.10	1.82	
Density (#/2)	1012	325	363	363	1165	363	325	573	267	38	573	516	306	420	497	

APPENDIX 13: Distribution of Phytoplankton at Cliff Lake, expressed in numbers per liter; July, 1981*

TAXA	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Stn. 13	Stn. 14	Stn. 15
<i>Cyanophyta</i>															
<i>Microcystis</i> sp.										5					
<i>Oscillatoria limnetica</i>	5675	9545	15345	22405	10960	8335	7955	10970	31075	10910	16470	11975	7245	12690	8935
<i>Oscillatoria</i> sp.					5										
<i>Chlorophyta</i>															
<i>Cosmarium</i> sp.														5	
<i>Chrysophyta</i> (Bacillariophyceae)															
<i>Asterionella formosa</i>	75	20	305	285	10	175	70	145	70	10	10	120	130	125	80
<i>Fragilaria capucina</i>	5		5		5	15			75					5	
<i>Fragilaria crotonensis</i>															
<i>Gomphonema olivaceum</i>	5			10	5				15					5	
<i>Melosira</i> sp.					5										
<i>Nitzschia</i> sp.						35		5							
<i>Pinnularia</i>							5		5						
<i>Synedra ulna</i>		5													
<i>Chrysophyta</i> (Chrysophyceae)															
<i>Dinobryon sociale</i>	10	10	5				35	35	55	35	100	10	40	60	100
var. <i>americanum</i>															
<i>Pyrophyta</i>															
<i>Ceratium hirundinella</i>	10								15						

* Weather July 11 - 90% cloud cover, winds west 15 km/hr.

APPENDIX 14: Species list and estimated surface area (μ^2) of phytoplankton from Trout Lake; July, 1981

Taxa	Surface Area (μ^2)
Cyanophyta	
<i>Anabaena</i> sp.	500
<i>Chroococcus limneticus</i> Lemmermann	900
<i>Oscillatoria</i> sp.	1200
Chlorophyta	
<i>Closterium setaceum</i> f. <i>signmoideum</i> Irene-Marie	60
<i>Dictyosphaerium pulchellum</i> Wood	3000
<i>Pediastrum Boryanum</i> (Turp.) Meneghini	625
<i>Scenedesmus flexuosus</i> (Lemm.) Ahlstrom	750
Chrysophyta (Bacillariophyceae)	
<i>Asterionella formosa</i> Hassal	1500
<i>Cocconeis placentula</i> Ehrenberg	250
<i>Cyclotella</i> sp.	225
<i>Fragilaria capucina</i> Desmarziers	1625
<i>Melosira</i> sp.	3000
<i>Navicula</i> sp.	200
<i>Nitzschia signmoidea</i> (Ehr.) W. Smith	5000
<i>Pleurosigma</i> sp.	1500
<i>Rhizosolenia longiseta</i> Zacharias	500
<i>Stephanodiscus</i> sp.	2000
<i>Synedra acus</i> Kuetzing	150
<i>Synedra ulna</i> (Nitz.) Ehrenberg	1250
<i>Tabellaria flocculosa</i> (Roth) Kuetzing	4000
Chrysophyta (Chrysophyceae)	
<i>Dinobryon bavaricum</i> Imhof	200
<i>Dinobryon sociale</i> Ehrenberg	125
Pyrrophyta	
<i>Ceratium hirundinella</i> (Mueller) Schrank	2500

APPENDIX 15: Species list and estimated surface area (μ^2) of phytoplankton from Cliff Lake; July, 1981

TAXA	Surface area (μ^2)
Cyanophyta	10,000
<i>Microcystis</i> sp.	800
<i>Oscillatoria limnetica</i> Lemmermann	1,600
<i>Oscillatoria</i> sp.	
Chlorophyta	200
<i>Cosmarium</i> sp.	
Chrysophyta (Bacillariosphyceae)	
<i>Asterionella formosa</i> Hassal	1,500
<i>Fragilaria capucina</i> Desmarziers	1,250
<i>Fragilaria crotonensis</i> (Ehrenberg) Grunow	12,500
<i>Gomphonema olivaceum</i> (Lyngbi) Kutz.	300
<i>Melosira</i> sp.	1,200
<i>Nitzschia</i> sp.	375
<i>Pinnularia</i> sp.	1,000
<i>Synedra ulna</i> (Nitz.) Ehrenberg	2,400
Chrysophyta (Chrysophyceae)	
<i>Dinobryon sociale</i> var. <i>americanum</i> (Brunnthal) Backmann	50
Pyrrophyta	
<i>Ceratium hirundinella</i> (Mueller) Schrank	2,500